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OPEN LV

OPENING UP THE SMART GRID

Site Acceptance Tests

Test Record – Phase 2

ea technology

RIIO NIC NETWORK INNOVATION COMPETITION

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Contents

1 Introduction

1.1 Overall testing approach

The overall approach to testing the OpenLV solution has been defined in 'SDRC 1 – Specification Design & Testing'.

There are three distinct areas of testing for the OpenLV solution.

- **Factory Acceptance Tests** to verify the system and its components function correctly, including the operation and configuration of software components, and consequently that the overall system meets the requirements detailed in the Requirements Specification.
- **Site Acceptance Tests** to verify the solution meets the requirements in realistic, non-laboratory / controlled environment once the complete system has been installed on location in its final configuration. These tests verify that no damage occurred to the hardware during shipment and installation.
- **Cyber-security testing** to evaluate the cyber-security capabilities of the LV-CAP™ platform; these tests will be undertaken by a specialist provider.

The Factory Acceptance Tests (FATs) were undertaken in two stages and completed successfully, demonstrating the LV-CAP™ platform and ancillary equipment has been functionally tested and approved for deployment in the OpenLV Project trials.

As with the FATs, there will be two phases of Site Acceptance Tests (SATs), the first for the core OpenLV solution and the second to comprise the full solution, including the network automation elements; refer to Table 1 below for details of the components covered in each set of tests.

The current version of this document only details the tests for the Phase 1 SATs, and will be updated prior to the deployment of the network automation hardware.

SATs will only be undertaken on the first iterations of equipment installed for the project. For example, SATs for the 'Core System' will be undertaken for the first two pairs of systems deployed.

A set of detailed commissioning tests will be utilised on all site installations utilising Alvin Reclose™ devices to ensure correct operation.

These commissioning tests will be detailed and recorded separately to this document.

Table 1 - Summary of Site Acceptance Testing

Component	Category	SAT 1 OpenLV Core System	SAT 2 OpenLV Full Solution
LV Network Automation Hardware	Hardware	No	Yes
LV Monitoring Hardware	Hardware	Yes	Yes
OpenLV Platform	Hardware	Yes	Yes
Application Deployment & Management Server	Hardware	Yes	Yes
Cloud Hosted Server	Hardware	Yes	Yes
Communications Infrastructure	Hardware	Yes	Yes
LV-CAP Operating System	Software	Yes	Yes
Temperature Sensor app	Software	Yes	Yes
Load Profile Predictor app	Software	Yes	Yes
Peer to Peer Communications app	Software	Yes	Yes
LoadSense app	Software	No	Yes
Network Meshing app	Software	No	Yes
Dynamic Thermal Ratings app	Software	No	Yes
Nortech Communications app	Software	Yes	Yes
Electrical Sensor app	Software	Yes	Yes
Lucy Electric Gridkey Communications app	Software	Yes	Yes

Cyber-security testing is a multi-phased process and will not be completed until after the deployment of the trial hardware and a period of operation to evaluate performance. At the time of writing, prior to initial hardware deployment, a cyber-security evaluation has been undertaken to confirm the suitability of the LV-CAP™ platform for deployment as part of the trials.

NCC Group, the cyber-security specialised contracted to the Project have confirmed cyber-security tests and overall evaluation will be undertaken in parallel with the equipment deployment and will inform updates to the platform where necessary.

It is not intended to undertake tests relating to the cyber-security requirements as part of the hardware and functionality tests. Due to the nature of cyber-security testing, particularly penetration testing, the duration required for effective evaluation, and the potential conflict of simultaneous tests being undertaken, these requirements will be appraised separately by NCC Group, the OpenLV Project's cyber-security specialist.

2 Site Acceptance Tests Methodology

At the point of equipment deployment, elements of the overall OpenLV solution, (e.g. the LV-CAP™ platform code, the management and control server, and software containers), are unchanged from the testing undertaken within EA Technology's and project partner facilities to the point of deployment to site. Furthermore, with the majority of system components being software based, these are unlikely to be affected by a physical change in the hardware's location.

Therefore, the SATs detailed in this document focus on ensuring the system continues to operate as expected despite no longer being based in a controlled environment and following the disconnection, relocation and reconnection of the system's primary hardware and ancillary devices. The SATs therefore comprise a number of tests to verify the system's overall functionality is unaffected following transport and installation.

Due to the interconnected nature of the system and components, rather than replicating the full range of individual tests undertaken as part of the FATs, the SATs can be undertaken through a reduced number of tests by utilising targeted testing. This ensures the full process of operation, from the point of data gathering from the LV network to uploading the processed information, generated from the data, to the connected servers and therefore, that each individual component, comprising predominantly of software containers, is operating correctly.

The tests outlined below have been scheduled to minimise repeated tasks and wherever possible, to enable a single action, or sequence of actions to demonstrate that multiple requirements are met, and consequently multiple modules and software components are functioning as expected.

These 'Phase 2' tests are only intended to demonstrate the capability of the trial platform with respect to the implementation of the Alvin Reclose™ units and associated control capability.

This covers the software and hardware elements shown in Table 1 as being not demonstrated in the Phase 1 tests.

All elements demonstrated as part of the Phase 1 tests are utilised in the overall system, providing input information to the DTR, Loadsense and meshing applications. These previously tested elements have not been changed since the initial deployments and as such will not be retested as part of the Phase 2 tests.

The Phase 2 tests will require an extended period due to the nature of the software applications being tested. The system requires a period of several weeks to begin calculation of load / thermal forecasts considered reliable enough for network control.

During the Phase 2 FATs it was possible to accelerate the process in the laboratory environment, but this is not a viable approach when installed on the LV network. Consequently, it is necessary to install the equipment, undertake the immediately possible tests, and revisit at a later point to finalise the results.

2.1 Setup Details

2.1.1 Login details

To undertake the tests detailed in this document, access to the LV-CAP™ platform will be achieved utilising a remote access method via the platform's router modem.

To undertake the tests, the following additional computers, beyond the LV-CAP™ platform, will be required:

- 1x laptop on-site to provide:
  - access to and control of the LV-CAP™ platform via the router modems within the enclosure;
  - access to the OpenLV Project's iHost server for verification purposes.

2.2 Pre-deployment work

Prior to the deployment of equipment to the network for the trials, each set of hardware will be set-up and tested by EA Technology to confirm it is operating as expected. These tests will cover:

- Correct functionality of the LV-CAP™ platform;
- Correct functionality of the GridKey MCU520 platform;
- Connectivity between the MCU 520 and the LV-CAP™ platform;
- Connectivity between the LV-CAP™ platform and router modem;
- Successful bi-directional communications through the router modem;
- LV-CAP™ access to the iHost Command and Control Server; and
- LV-CAP™ access to the Lucy Electric Cloud Data Server.

All sets of LV-CAP™ equipment will be tested and verified as being fully operational before shipment to site.

The final sites to be installed as part of the Method 1 trials will have the Alvin Reclose™ hardware included as part of the installation, along with the necessary software interface to enable control by the LV-CAP™ platform.

The Phase 2 SATs will verify successful operation of the hardware / software interface of the LV network meshing capability following successful FATs at EA Technology's offices.

Between testing at EA Technology and installation on-site, the following related elements will be changed for all locations:

- **Location:** Whilst the LV-CAP™ platforms will communicate via the 3G / 4G network through the internal router modem, the units will be reactivated onsite for connection to different cell towers. This requires verification that the system can establish communication links to the rest of the Project systems and the paired LV-CAP™ platform.
- LV Board: The Alvin Reclose™ units will be installed on a live, LV Network rather than a simulated (test) network at EA Technology.
- Real data: Rather than being provided with pre-populated data, at a 'faster than real time' rate for testing purposes, the system will be processing 'live, real-time data'.

2.3 Phase 2 Site Acceptance Tests – Deployment with Alvin Reclose™ units.

For the avoidance of doubt, the majority of sites fitted with the LV-CAP™ trial hardware will not have the Alvin Reclose™ equipment installed and so these tests will not be relevant for them.

Some sites in which the ISD enclosures and monitoring equipment are installed will be upgraded later in the project with the installation of ALVIN Reclose™ devices and separate SATs will be undertaken to verify the successful installation and operation of those components and associated software. This document will be updated to detail the Phase 2 tests in advance of the deployment of the ALVIN Reclose™ devices to implement the network automation functionality.

All equipment will be installed in accordance with the agreed method statements prior to commencing these tests.

Prior to commencing any SATs, the enclosure and Alvin Reclose™ units, shall be installed in the location agreed during the site surveys, as will the MCU520 platform, and all ancillary equipment (Rogowski coils and thermocouples). All cables shall be routed using cable ducts or equivalent, as available, and appropriate within the substation in question.

The enclosure shall not be energised and made live until all work elements are complete. Once energised, the ISD will be fully connected and energised, being left for a period of at least several minutes to enable it to initialise all software applications and communication links in preparation for the tests to commence.

2.3.1 On-site testing approach

The on-site testing approach will demonstrate the following high-level capabilities of the system once installed.

A system overview, highlighting the key hardware elements and the interconnecting communication links is shown below.

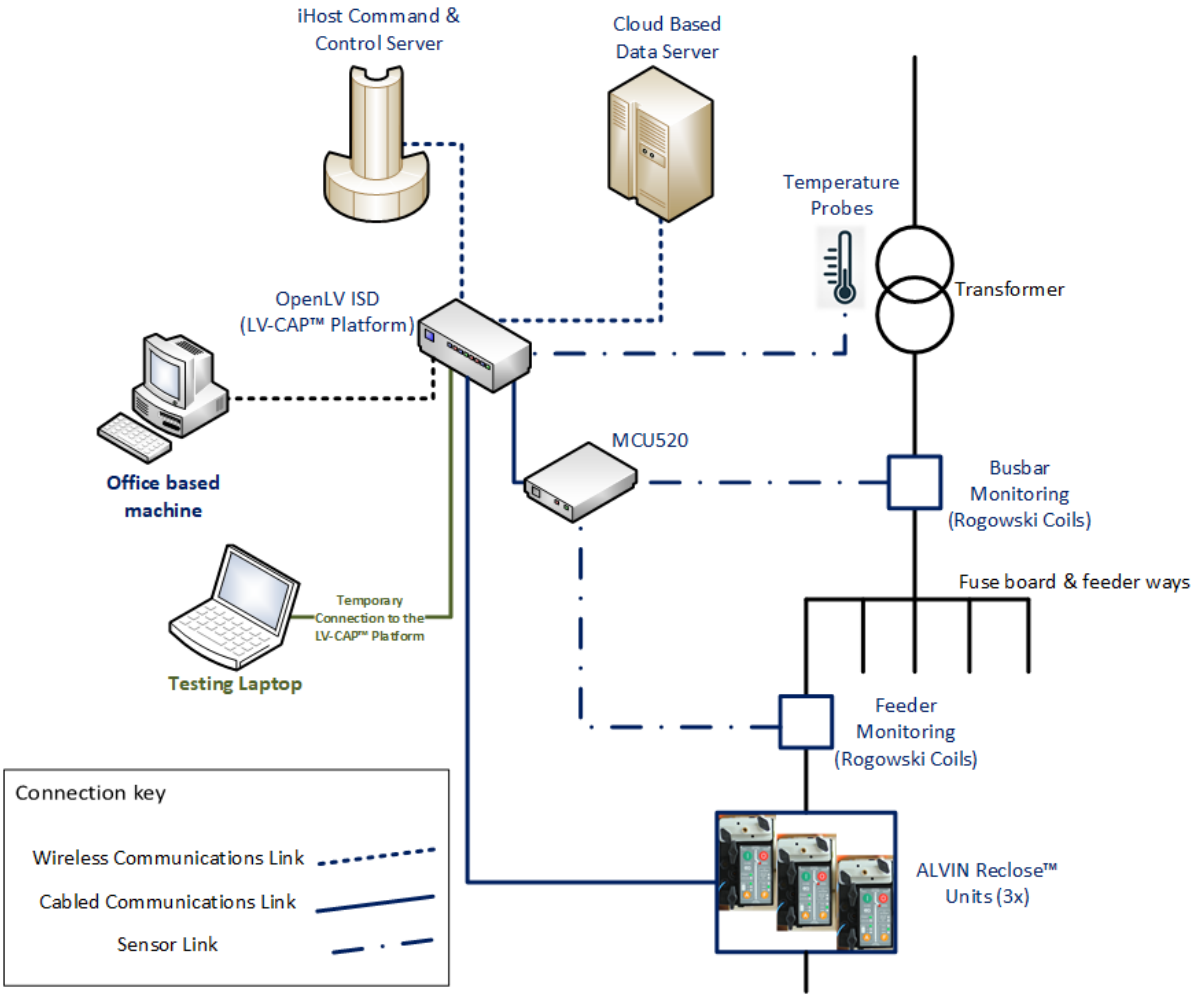


Figure 1 – OpenLV Trial System Overview

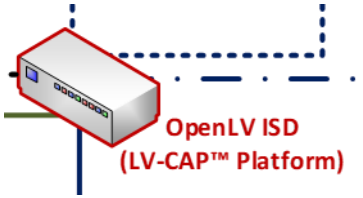
Each sequence of the initial SATs were designed to test a specific part of the system shown above; either individual components, or interconnections between them.

However, the initial SATs were not intended to test the incorporation of the Alvin Reclose™ devices as the necessary software and hardware links were not scheduled for completion at that stage of the project.

The second stage SATs were to demonstrate the capability of the LV-CAP™ system to autonomously control the Alvin Reclose™ devices when connected to the LV network.

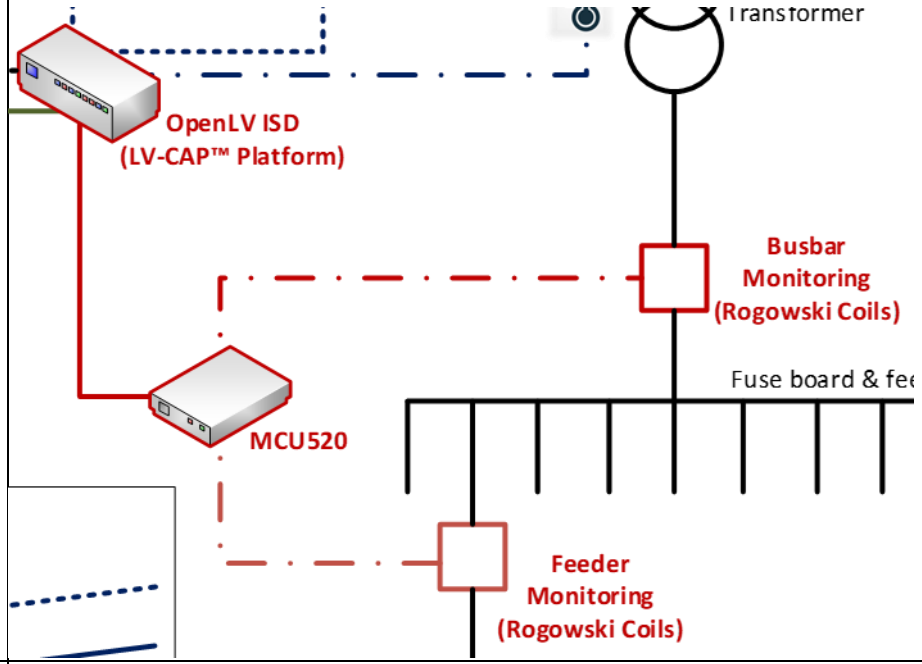
3 Site Acceptance Tests

Test: SAT 1.01

Objective:	To confirm the industrial PC is operational, has activated successfully and that the LV-CAP™ platform is operational.			
Elements under test:	 This test sequence is concerned with verifying the Ruggedised PC within the Intelligent Substation Device remains operational. In order to be successful, the following elements must be functioning correctly: • Nortech Communications Container • Load Profile Predictor • CSV Data Recorder • Lucy Electric Sensor Container • Lucy Electric Communications Container • Temperature Sensing Application			
Starting condition:	The ISD enclosure shall be installed in line with the method statement and specific on-site requirements. It will have been energised and left for a period of several minutes to enable the system to start-up without interference.			
Test sequence:		***Action***	***Expected result***	***Pass / Fail***
	1	Open the enclosure and connect the testing laptop to an ethernet port on the industrial PC.		
	2	Log into the LV-CAP™ platform.	A secure connection should be established. If the system is not online, disconnect the testing laptop, restart the ISD enclosure then restart this test sequence.	Pass ✓ Fail ☐

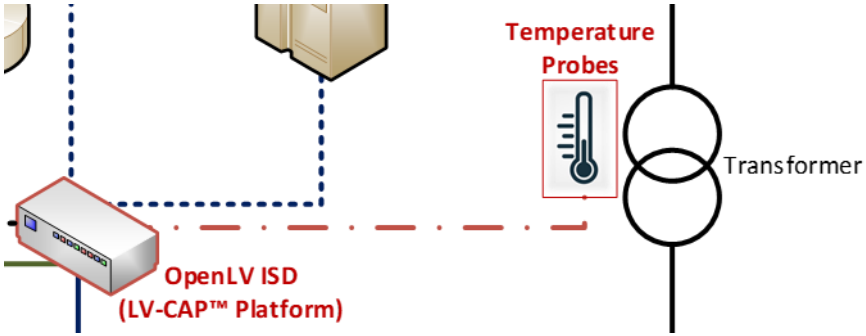
	3	Access the management console for the LV-CAP™ platform and verify that expected software containers are operational.	The following software containers should be active: • Nortech Communications Container • Load Profile Predictor • CSV Data Recorder • Lucy Electric Sensor Container • Lucy Electric Communications Container • Temperature Sensing Application	Pass ✓ Fail ☐
Comments:				

Test: SAT 1.02

Objective:	To verify the MCU520 is communicating successfully with the LV-CAP™ platform and that the sensors providing data to the MCU520 have been installed correctly.
Elements under test:	 This test sequence is concerned with verifying the MCU520 and associated monitoring devices (Rogowski Coils) are operational and correctly installed. In order to be successful, the following elements must be functioning correctly: • Rogowski Coils; • MCU520; • Wired communications link between the MCU520 and the LV-CAP™ platform; and • MCU520 Sensor Container.
Starting condition:	The ISD enclosure shall be installed in line with the method statement and specific on-site requirements. This test sequence shall follow from the previous test, 1.01, and consequently, the testing laptop shall be already connected. If for any reason the testing laptop is not connected, follow step 1 of Test SAT: 1.01 before commencing the steps of Test SAT: 1.02.

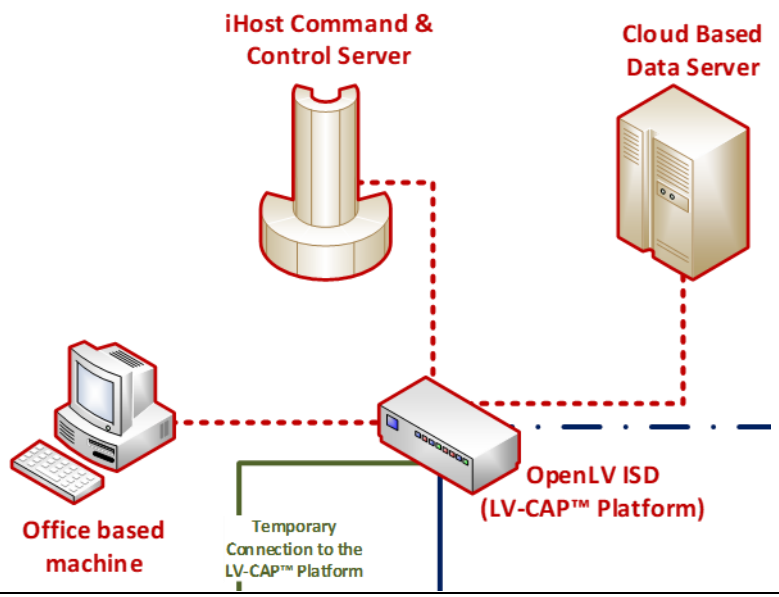
Test sequence:		*Action*	*Expected result*	*Pass / Fail*
	1	Using the testing laptop, monitor the MQTT message broker and confirm data readings are provided by the MCU520 platform at 1-minute intervals.	Data should be published onto the message broker at 10-second intervals, providing the voltage at the busbars and current readings from both the Rogowski coils.	Pass ✓ Fail ☐
	2	Identify a suitable approach to use the portable ammeter to measure the current in each phase on the connection to the busbars.		
	3	Using the portable ammeter, monitor the current in the first phase of the power connector from the transformer and compare this reading against the equivalent reading published to the message broker.	The two readings should be the same, within a reasonable margin for error. If not, verify that the busbar Rogowski Coils are installed correctly (right direction) and connected to the correct terminal on the MCU520.	Pass ✓ Fail ☐
	4	Compare the three phase angles reported to the message broker.	The three phases should be separated by approximately 120 degrees, within the margins of reasonable monitoring error.	Pass ✓ Fail ☐
	5	The ability to complete the above tests provides assurance that the sensors, connections to the MCU520 platform and communication link between the MCU520 and LV-CAP™ platform are operating correctly.	It is expected that LV network readings will be published to the message broker allowing the previous stages to be successfully completed.	Pass ✓ Fail ☐
Comments:				

Test: SAT 1.03

Objective:	To verify that the thermocouples are providing reasonably accurate data into the LV-CAP™ platform.
Elements under test:	 This test sequence is concerned with verifying the thermocouples are connected correctly to the LV-CAP™ platform and are functioning as expected. In order to be successful, the following elements must be functioning correctly: • Thermocouples (multiple, but quantity site dependent); • Digital I/O module; and • Thermal monitoring software container.
Starting condition:	The ISD enclosure shall be installed in line with the method statement and specific on-site requirements. This test sequence shall follow from the previous test, 1.01, and consequently, the testing laptop shall be already connected. If for any reason the testing laptop is not connected, follow step 1 of Test SAT: 1.01 before commencing the steps of Test SAT: 1.03.

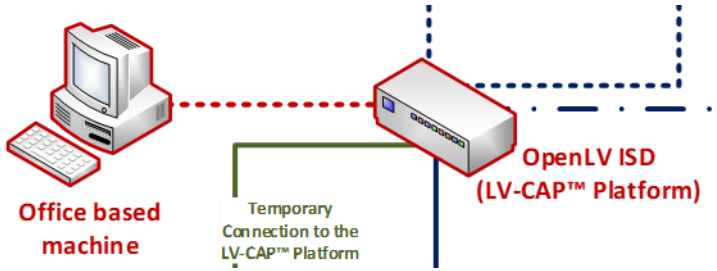
Test sequence:		*Action*	*Expected result*	*Pass / Fail*
	1	Using the testing laptop, monitor the MQTT message broker and confirm data readings are provided by the thermal monitoring software at the following intervals: • Transformer: 1-minute. • Substation: 10-seconds. • Ambient: 10-seconds.	Data should be published onto the message broker at the detailed intervals, providing temperature readings for each connected thermocouple.	Pass ✓ Fail ☐
	2	Using the handheld thermometer, determine the outdoor air temperature of the substation in close proximity to the location of the thermocouple installed within the radiation shield.	The reading provided by the thermocouple should be reasonably close to the separately monitored value.	Pass ✓ Fail ☐
	3	If installing in an indoor substation: Using the handheld thermometer, determine the ambient air temperature of the substation in close proximity to the location of the thermocouple installed within the substation.	The reading provided by the thermocouple should be reasonably close to the separately monitored value.	Pass ✓ Fail ☐ N/A ☐
	4	In comparison to the temperature readings determined in steps 3 and 4 above, determine if the measured reading from the transformer thermocouple appears reasonable.	The reading provided by the transformer thermocouple should be warmer than the ambient air temperatures, although site specific conditions will determine by how much.	Pass ✓ Fail ☐
Comments:				

Test: SAT 1.04

Objective:	To verify that that data is being received by the iHost control server and the Cloud Data Server.
Elements under test:	 This test sequence is concerned with verifying the router / modem is correctly recorded as being installed at the location in question and that the mobile data connection is capable of allowing remote access to the unit. In order to be successful, the following elements must be functioning correctly: • Router / modem module; • Mobile data network; • Connection to iHost Command and Control Server; and • Connection to Cloud Based Data Server.
Starting condition:	The ISD enclosure shall be installed in line with the method statement and specific on-site requirements. This test does not require the use of the testing laptop, if it is still connected from the previous test sequence, disconnect it from the LV-CAP™ platform but do not close and seal the enclosure.

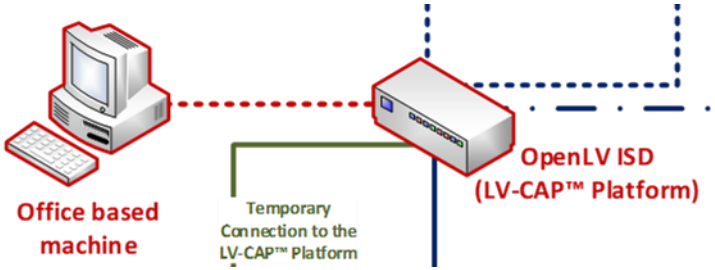
Test sequence:		*Action*	*Expected result*	*Pass / Fail*
	1	Installation crew to login to the iHost Command and Control Server and verify that the LV-CAP™ platform in question has connected to the server and transferred data, at 10-second intervals.	iHost server contains data from the system having been uploaded since installation.	Pass ✓ Fail ☐
	2	Installation crew to login to the iHost Command and Control Server and verify that the LV-CAP™ platform in question has connected to the server and transferred data, at 10-second intervals.	Cloud based data server contains data from the system having been uploaded since installation.	Pass ✓ Fail ☐
Comments:				

Test: SAT 1.05

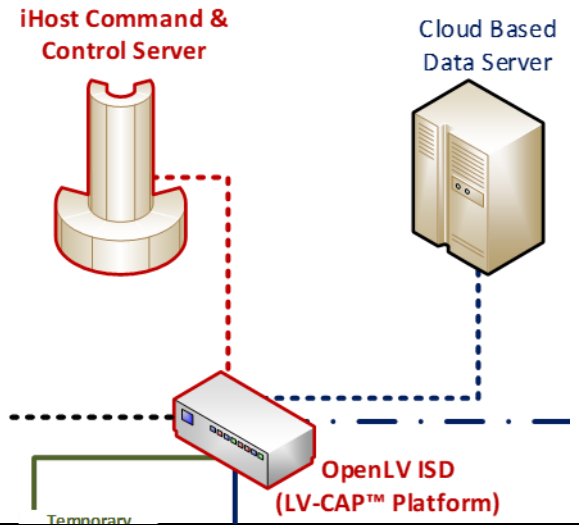
Objective:	To verify that: 1. The router – modem and SIM card combination installed within the ISD is correctly recorded; 2. The router – modem can be remotely accessed; and 3. That data transfer to the servers resumes after a system restart.		
Elements under test:	 This test sequence is concerned with verifying the router / modem is correctly recorded as being installed at the location in question and that the mobile data connection is capable of allowing remote access to the unit. In order to be successful, the following elements must be functioning correctly: • Router / modem module; and • Mobile data network.		
Starting condition:	The ISD enclosure shall be installed in line with the method statement and specific on-site requirements. This test does not require the use of the testing laptop, if it is still connected for any reason, disconnect it from the LV-CAP™ platform but do not close and seal the enclosure.		
Test sequence:	***Action***	***Expected result***	***Pass / Fail***
2	Office-based crew to access the router / modem using the process detailed in Appendix A.	Installation crew should be able to access the router / modem command console.	Pass ✓ Fail ☐

	3	Whilst the observing the console, the office-based test crew should trigger a hard-rest of the platform.	If successful, the power relay for the LV-CAP™ platform will illuminate, confirming the correct modem was being communicated with and that remote reset capability is available for the site. Site-based test crew will confirm successful shutdown of the unit through lack of LED activity on network ports.	Pass ✓ Fail ☐
	4	Office-based test crew to re-energise the LV-CAP™ platform.	Site-based crew, will observe the relay light deactivate, demonstrating power has been restored the LV-CAP™ platform. Network ports on the platform will begin flashing signifying restoration of power to the unit.	Pass ✓ Fail ☐
Comments:		This test was undertaken remotely, from EA Technology's Capenhurst offices.		

Test: SAT 1.06

Objective:	To verify that the LV-CAP™ platform resumes communication with the iHost and Cloud Data Servers following a system restart.		
Elements under test:	 This test sequence is concerned with verifying the router / modem is correctly recorded as being installed at the location in question and that the mobile data connection is capable of allowing remote access to the unit. In order to be successful, the following elements must be functioning correctly: • Router / modem module; and • Mobile data network.		
Starting condition:	The ISD enclosure shall be installed in line with the method statement and specific on-site requirements. This test does not require the use of the testing laptop, if it is still connected for any reason, disconnect it from the LV-CAP™ platform then close and seal the enclosure.		
Test sequence:	***Action***	***Expected result***	***Pass / Fail***
1	Office-based test crew to login to the iHost Command and Control Server and verify that the LV-CAP™ platform in question has re-connected to the server and is transferring data, at the expected rate for each data point.	System will restart following the restoration of power and following a period of a few minutes, recommence uploading data to the servers.	Pass ✓ Fail ☐
Comments:			

Test: SAT 1.07

Objective:	To verify that remote update capability of the LV-CAP™ platform configuration can be achieved.
Elements under test:	 This test sequence is concerned with verifying the router / modem is correctly recorded as being installed at the location in question and that the mobile data connection is capable of allowing remote access to the unit. In order to be successful, the following elements must be functioning correctly: • IHost Command & Control Server; • Router / modem module; and • Mobile data network.
Starting condition:	The ISD enclosure shall be installed in line with the method statement and specific on-site requirements. This test does not require the use of the Testing Laptop; if it is still connected for any reason, disconnect it from the LV-CAP™ platform then close and seal the enclosure. The LV-CAP™ platform shipped following testing with the sensors configured for 10-second reporting and the outputs of those sensors assigned for upload to the iHost and Cloud Based Data Servers.

Test sequence:		*Action*	*Expected result*	*Pass / Fail*
	1	Office-based test crew to login to the iHost Command and Control Server and change the configuration settings for the site in question such that sensor reporting is only required at one-minute intervals.		Pass ✓ Fail ☐
	2	Office-based test crew to verify that data reporting back to the iHost and Cloud Based Data Servers reduces from a rate of once every ten seconds to once every minute.	The LV-CAP™ platform will reduce the rate of data capture and this will be reflected in a reduction in the data uploaded to the two servers.	Pass ✓ Fail ☐
Comments:				

OpenLV system tested elements

The below diagram, shows each element, (highlighted in red) of the deployed system that has been tested, as part of the Phase 1 SATs.

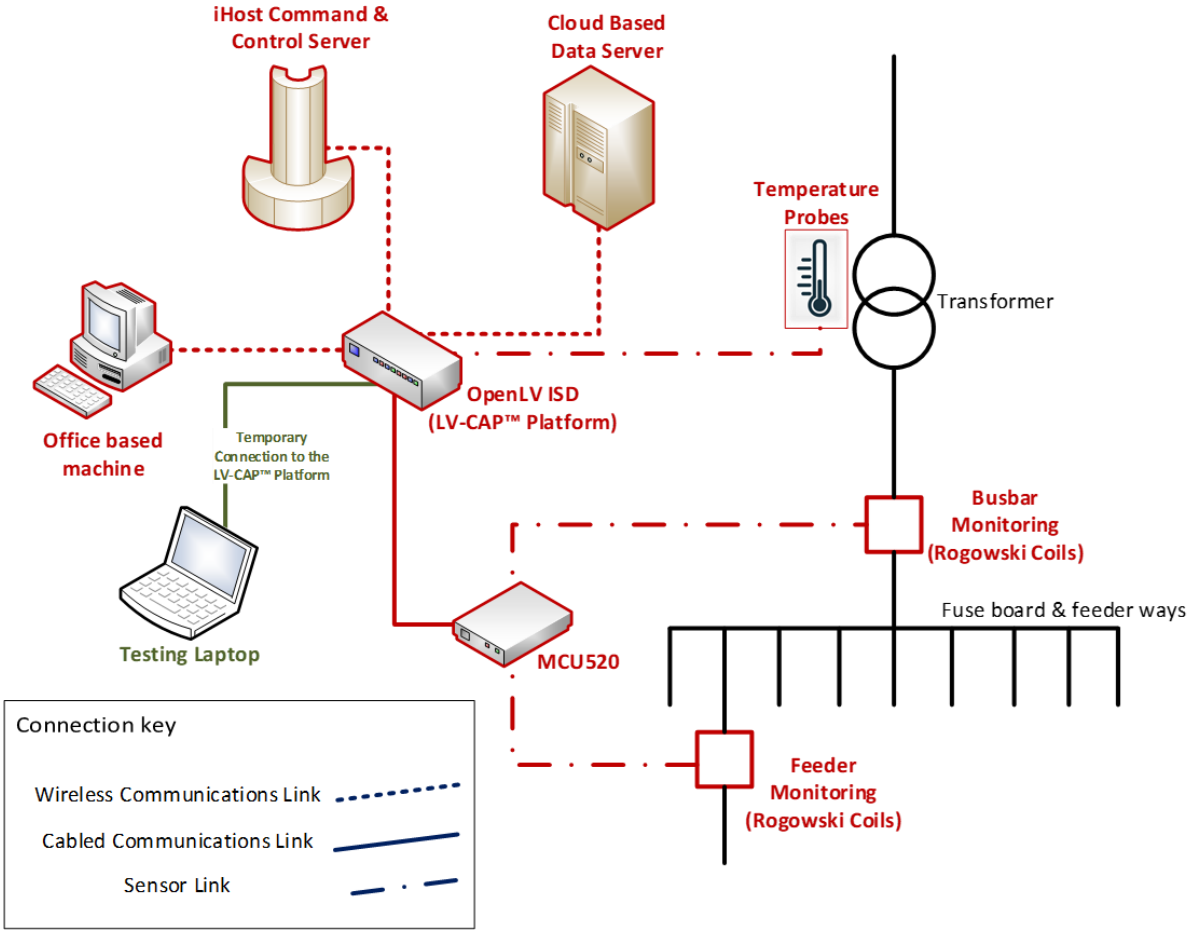


Figure 2 - OpenLV Trial System - Tested Elements

4 Sign-off and acceptance

It is acknowledged by all those in attendance at the Site Acceptance Tests (SATs) undertaken on the OpenLV LV-CAP™ Trial system at the location of…

……

on the date of…… and with respect to test 1.05, on the date of

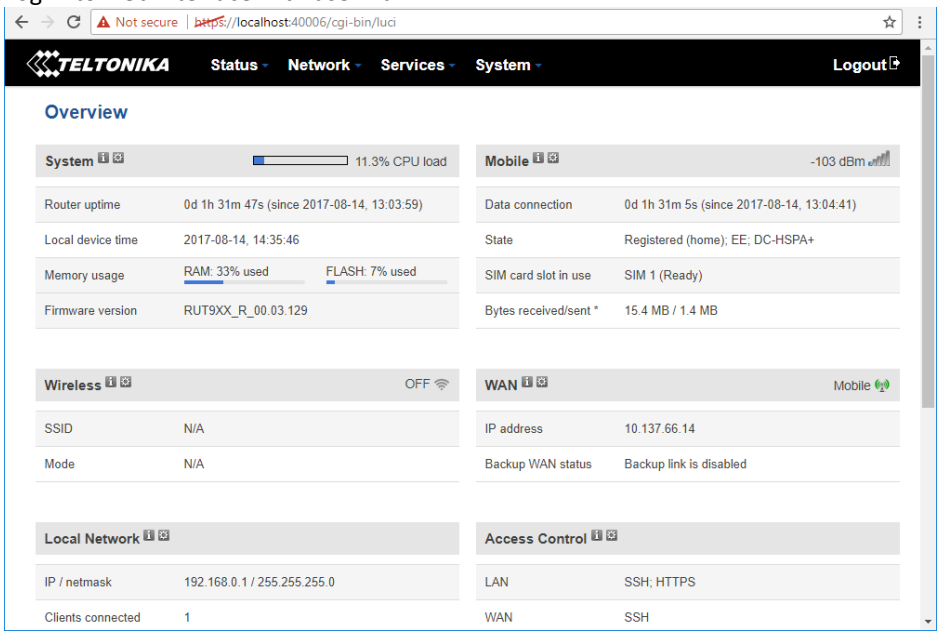
……that the results and comments detailed against each test in this document are a true record of the tests outcome.

The tests were witnessed by:

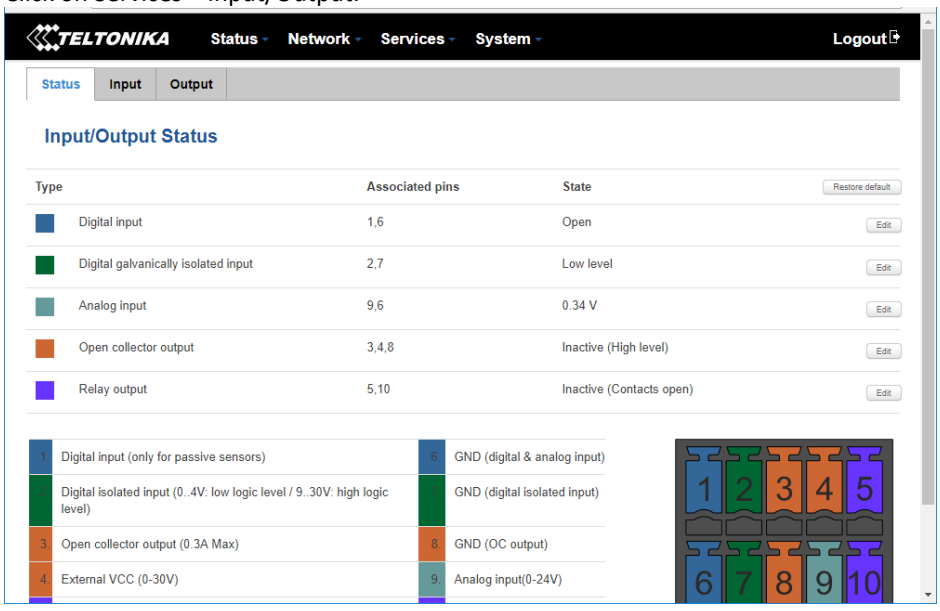
Name	Company & Role	Signature
Mark Dale	Innovation & Low Carbon Networks Engineer Western Power Distribution	
Tim Butler	Senior Consultant EA Technology	

Appendix A. Router / modem access routine

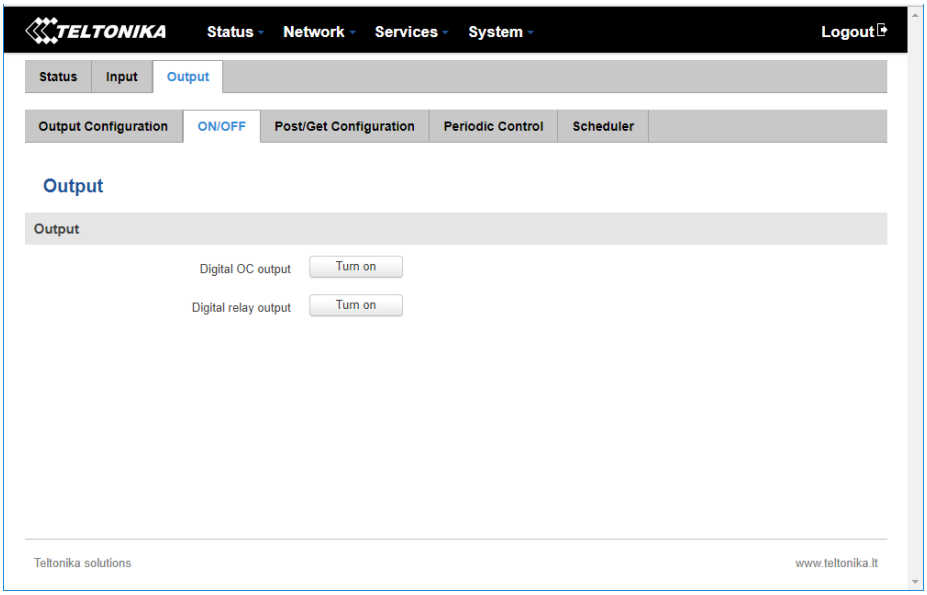
1. Connect to Wireless Logic SSL VPN (NetExtender) using user ssl_lv
2. Connect SSH session to 4G router using Putty:
   a. IP: see SIM records (10.x.x.x)
   b. Port: 8192
   c. Username: root
3. Forward local port “40006” (e.g.) to “localhost:443”
4. Open a web browser and connect to https://localhost:40006
5. Accept the security error for the self-signed router SSL certificate
6. Log in to web interface with user Admin



7. Click on Services > Input/Output.



8. Click on the Output sub-tab and then the ON/OFF sub-tab.



9. Click the “Digital OC output” Turn On button. This will remove power from the PC.

After the required delay, click the Turn Off button. This will re-apply power to the PC and allow it to start up.