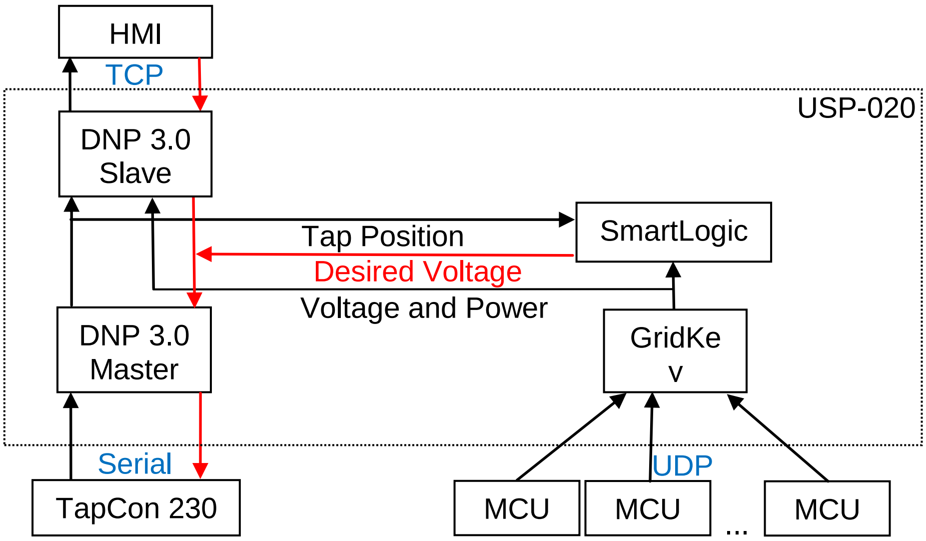
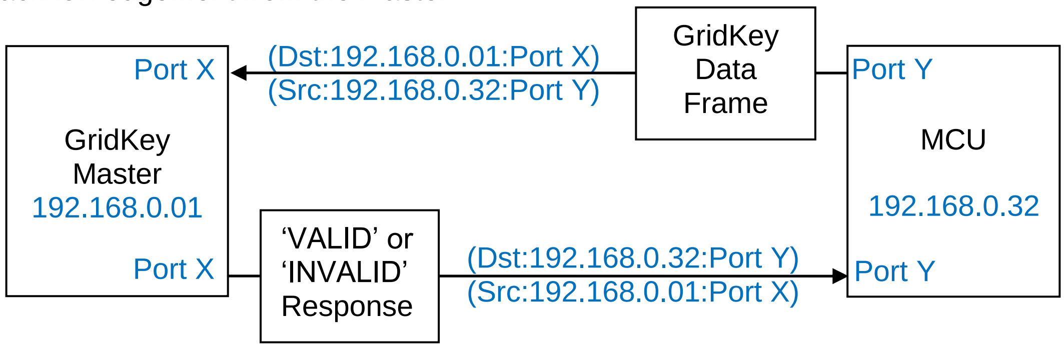
1. Systems Development

This project involved the integration of four separate components, an Automatic voltage Control Algorithm developed by the University of Manchester (UoM), measurement devices (MCU's) from Selex, a Tap Controller from Reinhausen (TapCon 230) and a HMI developed by CG. All of these components were integrated using CG's Universal Smart-control Platform (USP-020).



1.1 GridKey Master

Development of a "GridKey Master" interface component was required in order to retrieve the Voltage, Current and Power values from the Selex MCU's installed at the bus-bar, midpoints and endpoints of the network. The GridKey Master component acts as a server accepting connections over UDP from the various MCU's. Each MCU is pre-programmed with the IP address and port number on which to make the connection to the GridKey Master. Every Minute each MCU makes a connection to the Master and sends a block of data then waits for an acknowledgement from the Master.



Similarly MCU's can request a time synchronisation by sending a time request message to a pre-defined port number. The master responds with a message containing the current date and time.

1.2 Half Hour Averages

The GridKey devices present their data as averages calculated over a one minute period. The UoM algorithm required half hour averages for the data. So the GridKey Master validates each one minute average as it arrives to verify that it is part of the current half hour period and hasn't already been received and adds the value to a running total. At the end of the half hour period the running total is divided by the number of samples received and then broadcast as a half hour value. The reason that the MCUs currently report on a one minute period is that it provides a much better visibility of the operating state of the feeder network during each algorithm cycle period, and allows the performance of the solution to be assessed. It also supported any changes to reduce the algorithm cycle period without reconfiguration of the MCUs.

1.3 Integration of Tapcon 230

It was discovered when integrating the Tapcon 230 that there was an issue with the implementation of the DNP 3.0 protocol. As part of the initialisation the USP-020 requests all four classes of data in a single message (class 0 data is the equivalent of a General Interrogation in IEC 101, class 1, 2 & 3 are event data). If the Tapcon 230 didn't contain events then it responded correctly but if it had events then it would attempt to build a response but would only partially complete this response. The DNP 3.0 Master on the USP-020 was altered so it would send four separate requests for class 0, 1, 2 & 3 and thereby avoid a cycle of requesting all data, receiving an invalid message then requesting all data again.

1.4 System Implementation

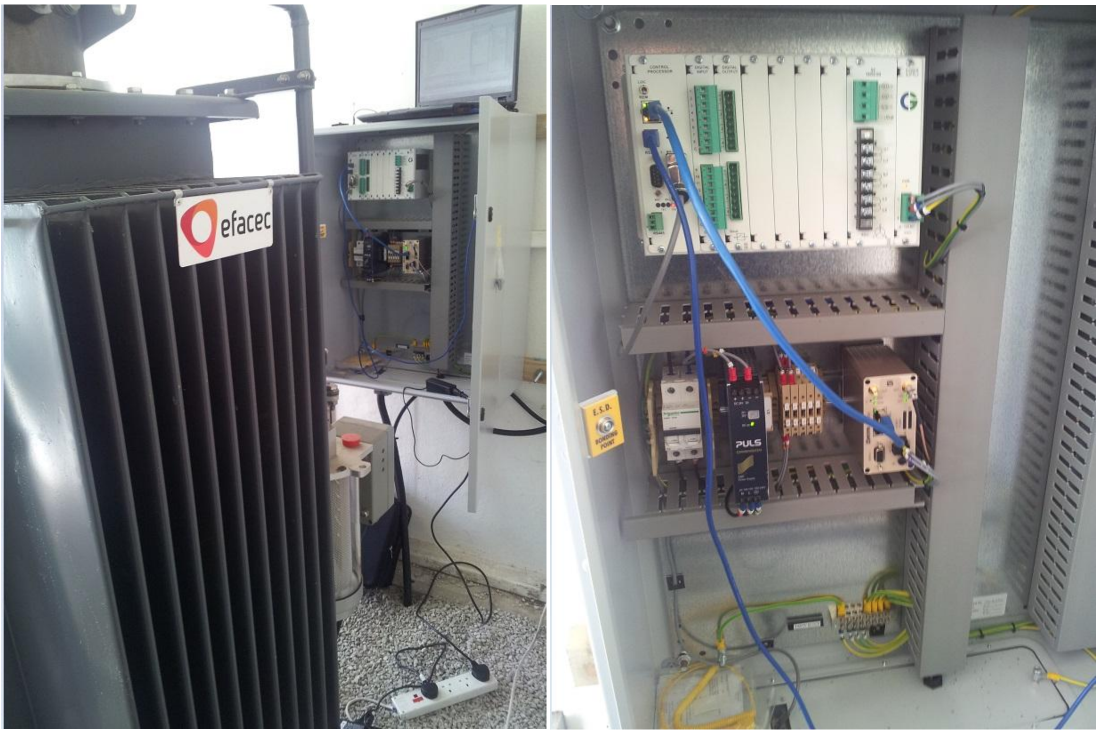
Initially the Tapcon 230 and MCU's were simulated in PLC code running in the SmartLogic application on the USP-020. A basic algorithm was also developed to simulate the generation of set-points for voltage control whilst UoM were developing their algorithm. This allowed testing and development to continue while CG, Selex ES and UoM developed their components in parallel. CG's HMI was developed at their facility in Jarrow and tested remotely against the test setup in Dublin.

When the GridKey Master interface was completed the MCU simulators were removed and replaced with MCU devices remotely accessed at Selex ES offices in Basildon, and later with MCU's in co-located at CG.

When the integration was completed with the Tapcon 230 the corresponding simulator was removed from the PLC code.

Finally when UoM had completed the algorithm development, the basic Voltage Control code was removed and UoM's code was integrated within the PLC code.

Bench testing of the system was carried out at the CG office in Jarrow and also in ENW's office in Manchester before installation on the ENW network at the Landgate and Leicester Avenue substations.



2. Details of Work Carried out

The project is intended to demonstrate an LV autonomous control system operating in an area of high PV penetration. The system is designed to operate as a closed loop control system – without human interaction. Alternatively the system can be monitored and controlled manually from the SCADA system if required. Metrology and status data is continually collected and stored.

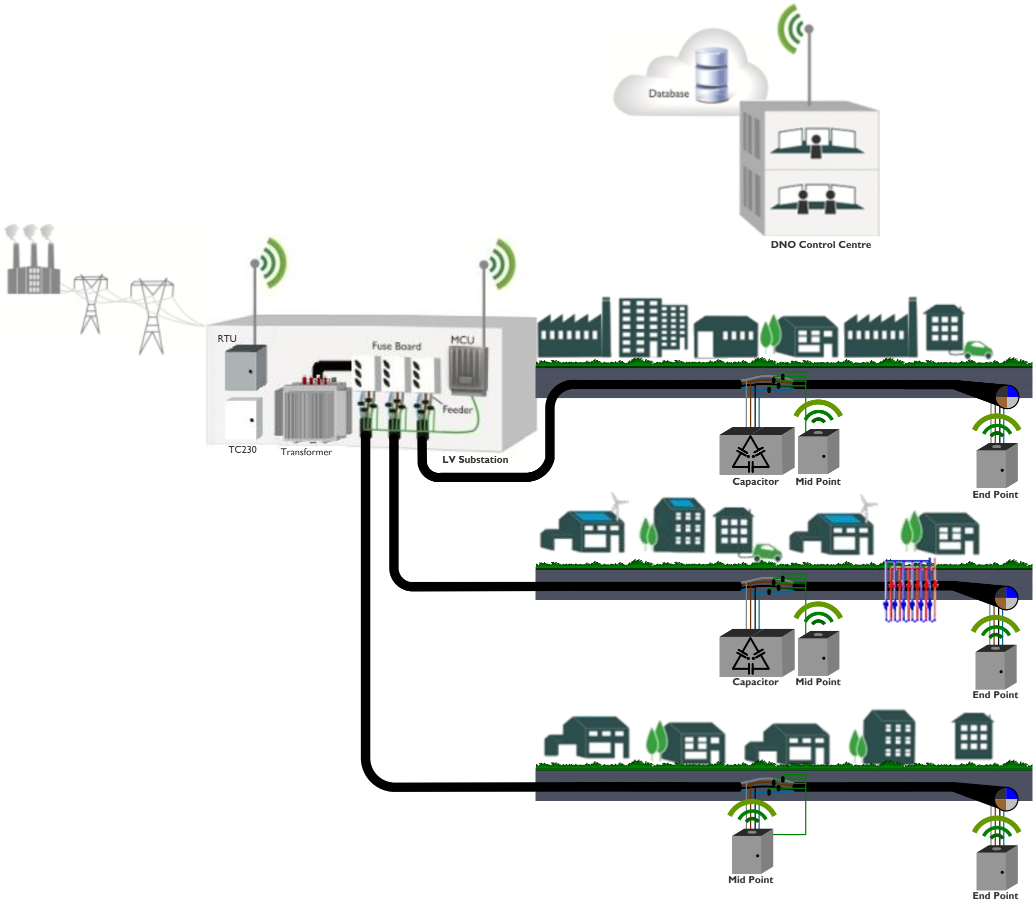
The two sites at Landgate and Leicester Avenue were selected due to the high DG penetration. These sites were the subject of two prior LCNF projects, Voltage management on Low Voltage Busbar Monitoring and Low Voltage Network Solutions. The work performed and learning derived from these projects will be built upon in this project.

The System is made up of the following elements:

- Metrology
- Communications
- Voltage Control
- Automation
- SCADA and Data Storage

Additionally extensive modelling has been undertaken in order to determine the optimum design and parameters for the system prior to implementation. During testing and after successful implementation the monitoring data has been analysed in order to verify and validate the control system.

In the previous projects transformers with On Load Tap Changers (OLTC) were installed at two substations. These were installed in parallel with the existing transformers, and existing transformers then disconnected. The OLTC controller and associated equipment were also installed, along with a Metrology and Communications unit (MCU 520). The following sections detail the new work carried out as part of the LoVIA project.



The LoVIA System

Metrology

In order to make correct control decisions at the substation, the voltage at the end of feeders needs to be known. This is achieved by installing metrology units as ‘voltage monitors’ along the feeders. In this project they are fitted at approximately the mid and end points of each feeder using Smart Joints (underground breech joints in the feeder cable to connect voltage and current sensors). For this project mid-point monitors were fitted however, it was recognised that the voltage would often be most extreme at the end of each feeder and so if this system was rolled out as business as usual it is likely that only end-point monitors would be fitted. However within this project the learning potential is increased by having the ability to monitor each feeder’s voltage profile in much more detail and also monitor the current and power flowing through each of the feeders at the mid-point.

Communications

Although this project was specifically not intended to try and solve communications issues, secure, reliable and robust communications networks are required to link the various elements of the system together in order that devices can exchange information and the system operate successfully..

The requirement is to communicate between mid/end point monitors and the RTU in the substation, a distance typically in the region of a few hundred meters. This type of communications would not typically utilise GSM/GPRS mobile cellular network communications, as the data costs would be relatively high. As such a number of communications media were reviewed specifically for this element of the communications network and a small subset were assessed. These communications media included:

- Ad-Hoc wireless networks
- WiMax networks
- Cellular networks (Centrally administered and Peer to Peer)
- Short wave radio links
- Powerline Communications

As a result it was decided to carry out a small scale trial of the powerline communications technology using the CG-ZIV PRIME PLC at selected points on the network to assess the viability of this technology for this type of application.

However for the overall project, GPRS cellular communications were considered the lowest risk and therefore preferred technology for all the communication within the LoVIA project.

Power Line Communications small scale trial

The intent was to prove whether the technology could provide robust communications between mid-points, end points and the substation, utilising only the connections to the local feeder.

Power line communications works by sending signals along the electrical transmission network, so a modem fitted to the busbar of a substation could communicate with other modems connected to that substation’s feeders.

Due to their maturity, widespread use and low cost ZIV PRIME power line modems appeared to be an attractive choice for communications. In a business as usual deployment the unit cost of these PLC modems would be particularly attractive.

PRIME (PoweRline Intelligent Metering Evolution) is an open standard Physical and Mac layer, where different manufacturer’s equipment should operate together. PRIME is based on OFDM multiplexing in CENELEC-A band and reaches up to 130 kbps raw data rate.

The PRIME standard is heavily utilised for smart meters in Spain and elsewhere in Europe.

In this trial setup a PLC modem was installed alongside each MCU and RTU. These would form a reconfigurable network where intermediate PLC modems would act as repeaters for more distant PLC modems. The substation would contain a master PLC modem which would communicate with the RTU and a cellular modem for backhaul communications to the SCADA system.

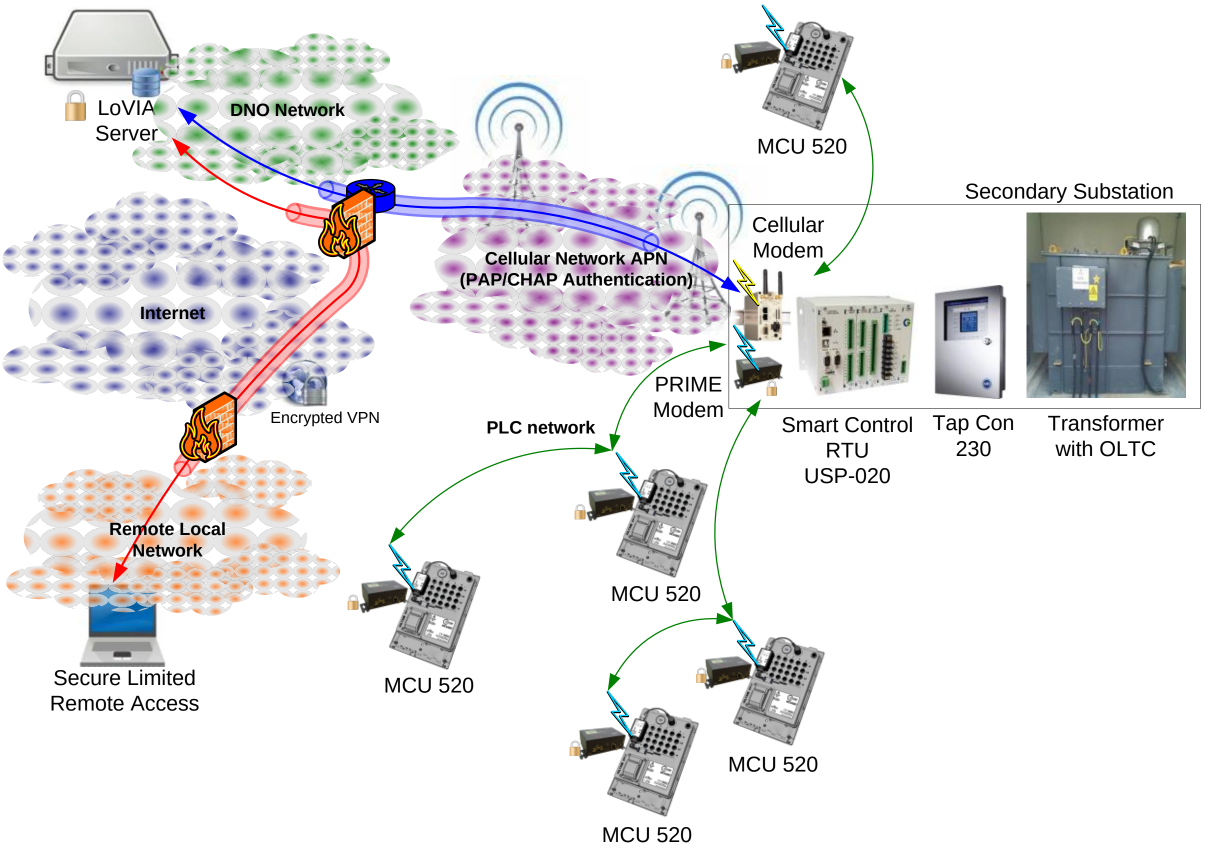
MCUs and RTUs would communicate with the PLC and Cellular modems over an Ethernet interface, utilising DNP3 or proprietary communications protocols.

During the on-site trial the PLC Modems were seen to communicate robustly over unbranched feeders when tested at distances of up to 100m. With a PLC modem acting as a repeater at the mid-point the PLC modems were seen to communicate effectively on unbranched feeders of up to 200m.

However on feeders which were expected to be more challenging for the PLC PRIME modems, for example long feeders with branches or spurs, the PLC modems did not provide a robust communications medium.

This was believed to be due to a combination of signal attenuation, interference and reflections arising from the branched feeder. The limitation of placing modems which can act as repeaters only at the mid-points meant that using PLC PRIME modems operating within the CENELEC-A band would not be feasible for all feeders.

The modems were designed to be, and are typically, installed in denser networks with significantly shorter distances between modems – I.e. a Smart Meters deployment where each consumer premises can act as a repeater. In order to provide effective communications over a difficult feeder it would be necessary to fit one or more intermediate modems to act as repeaters. This could be within some existing equipment connected to the feeder, such as lamp posts, or with a new dedicated connection to the feeder. If rolled out more widely the necessity of PRIME repeaters would significantly complicate the installation of any LOVIA type system, unless a PLC network was already in place and secure access could be gained.



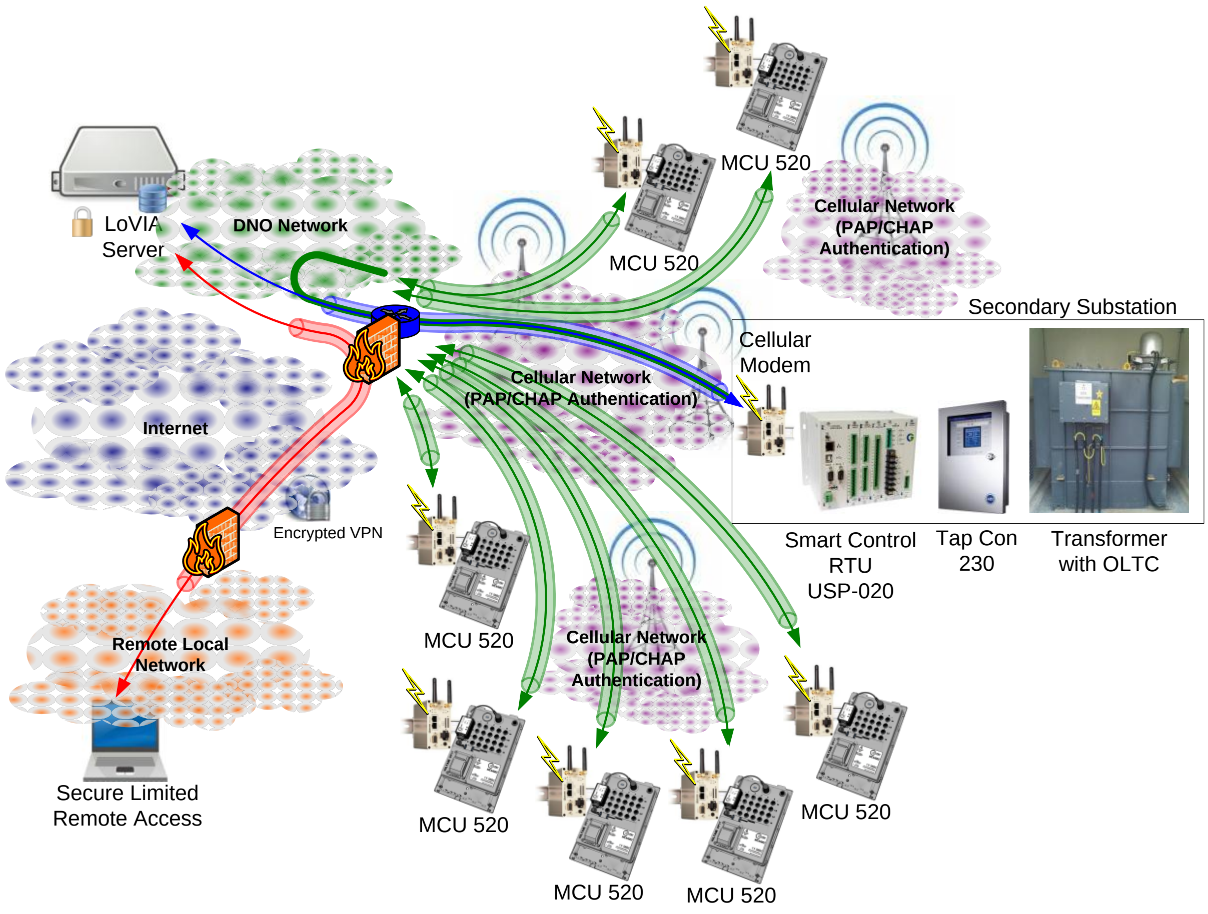
Initial Cellular Communications Concept

Cellular Communications

Cellular communications were selected as the means of communicating with mid and end points and the RTU as well as backhaul communications to the SCADA system.

A secure, private cellular network had been used successfully on previous projects and was to be used again for LoVIA. This private network was entirely segregated from the public cellular network with no access to the internet.

Previously the private network had been used as a ‘hub and spoke’ like network where terminal equipment could only communicate via the firewall associated with the ‘head end SCADA’ system. It was not possible for devices to communicate directly with one another, only via firewall policies which routed the packets between devices.

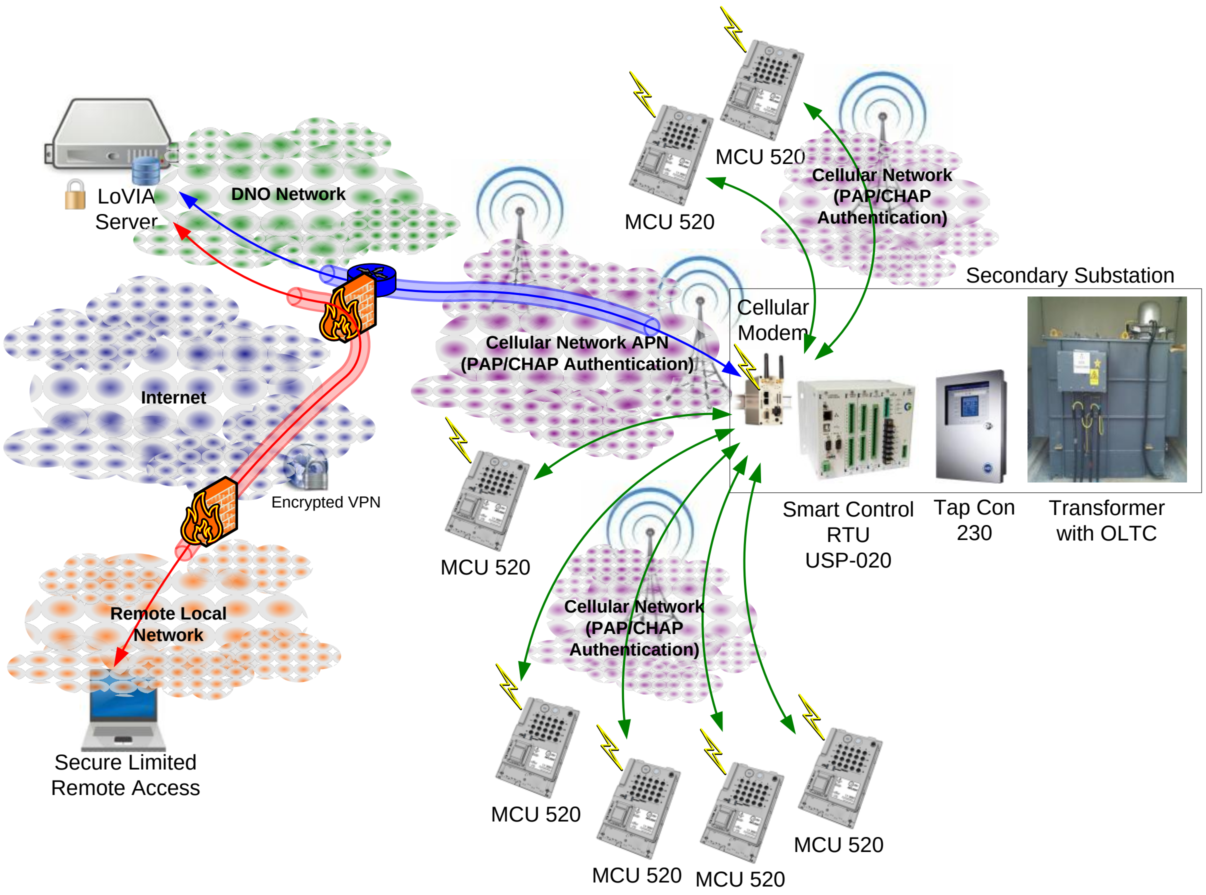


Initial Cellular Communications Concept

The initial cellular communications architecture involved a secure VPN being setup within the private Cellular network and packets routed at the firewall. This architecture proved unwieldy to set up and would be difficult to scale up for business as usual adoption.

ENW reviewed the security implications with the Cellular provider and agreed that a different architecture would be both more suitable and secure. Machine to Machine communications was enabled within this private network, which meant that all equipment on the private network could communicate with one another in a Peer to Peer fashion.

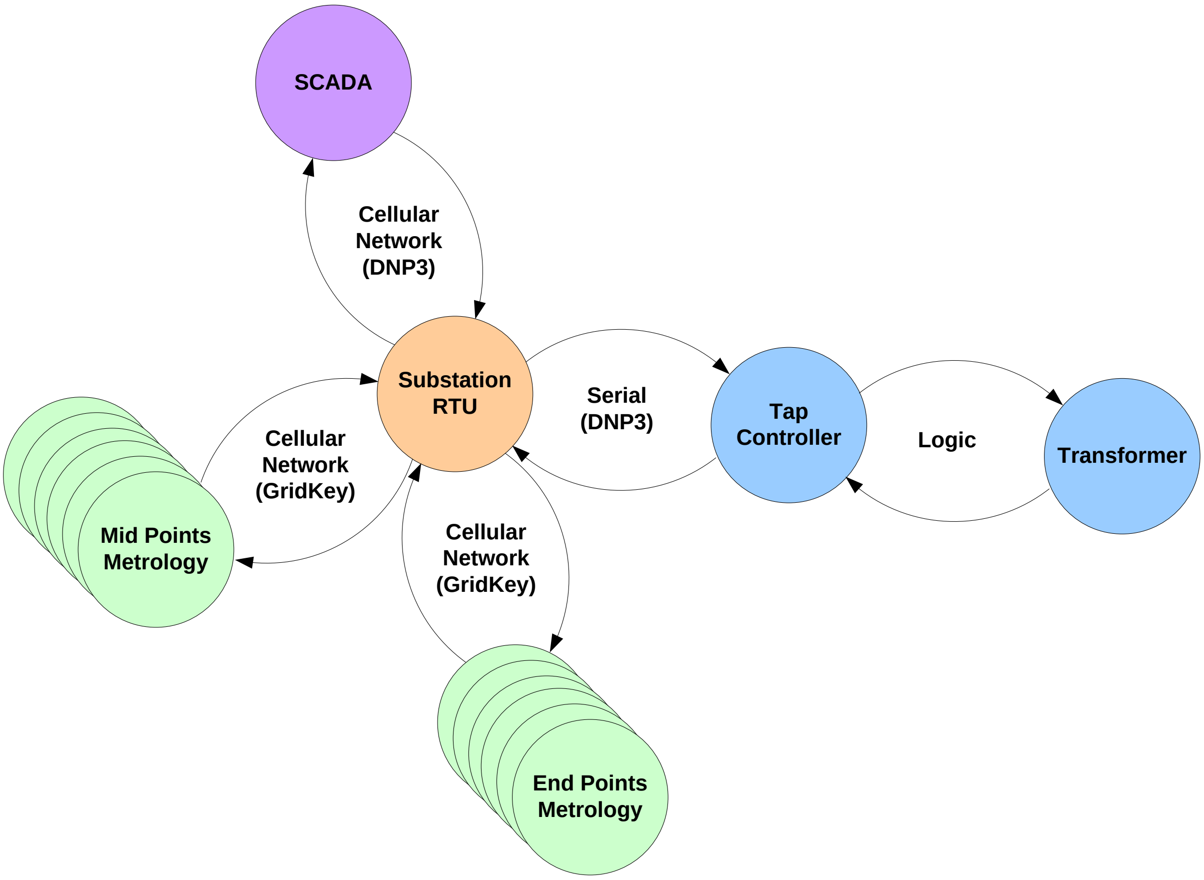
At the substation the cellular modem was set up to provide network address translation which significantly simplified the setup, especially if the system were rolled out more widely. Rather than requiring a unique IP addresses for each piece of terminal equipment, each substation could be setup identically with ‘default’ IP addresses, the only difference between each substation being the SIM card fitted in the cellular modem and its unique IP address.



Initial Cellular Communications Concept

The MCUs communicated directly with the RTU via the cellular modem and the RTU communicated directly with the SCADA system via the cellular modem.

Within the substation the RTU communicated with the Tap Controller via a serial interface.



Interactions between System Elements

Voltage Control

Voltage control is achieved in two ways, either via the Transformer with On Load Tap Changer (OLTC) and / or via capacitor banks.

The OLTC can adjust the transformer coil ratio whilst power is flowing through the transformer in a number of discreet steps. In this case there are nine steps with a 2% difference of the input voltage to the transformer between each step.

A Tap Change Controller, in this case a Maschinefabrik Rheinhausen Tap Controller 230, can be used to automatically change the tap position. In the LoVIA system this can be achieved in a number of ways:

- Manual position change using push button control
- Automatic tap change based upon the voltage measured between phases L1 and L2
- Remote control of the above modes via serial DNP3 from the RTU

50kVA ABB capacitor banks were installed as part of this project at the mid points of certain feeders. These capacitors switched ‘in’ or ‘out’ based upon the voltage measured at the capacitor connection point. At high voltages the capacitors switched out and at lower voltages capacitors switched in, reducing reactive power and increasing the voltage.

With multiple capacitor banks operating on the same LV network it was essential to determine the optimum settings for switching the capacitors in and out in order to avoid unstable hunting behaviour, where they would cycle repeatedly, potentially causing voltage issues and degrading equipment.

With the addition of an OLTC responding to a varying network voltage by changing the tap position, the prior situation could potentially be exacerbated.

These situations are explored in detail within the modelling performed by The University of Manchester and real measurements are used to verify the conclusions.

Automation

Safe Mode

In order to ensure any connected consumers were not adversely affected by the system a Safe Mode was developed in case of any system failure and will allow the system to enter the state which is least likely to cause problems on the network when there is a fault or an inadequate amount of information for the algorithm to make good decisions about what tap position the system should be in.

Safe Mode causes the system to revert to a particular tap position and avoid any further tap changes until the conditions have changed sufficiently for the system to operate effectively. At that point the system will exit Safe Mode and resume normal operation.

In addition at all times, whether in safe mode or not, it will be possible to manually control the system from the substation or via the SCADA system. The system is programmed to operate within a band; anything out of range will induce Safe Mode.

Out of range is defined as receiving a voltage reading outside the normal LV operating range of 180V to 260V inclusive. The Safe Mode tap position shall be equivalent to 1.04pu, which is equivalent to a substation L-N voltage of 240V assuming a primary voltage of 11kV.

In addition to this, of the 36 phases being measured, should 25% or more of these measurements become unavailable due to a comms error; the system will also enter Safe Mode.

Safe Mode will exit when the total number of offline measurements or out of range voltage readings are fewer than 25%.

Upon exiting Safe Mode, the algorithm shall remain at the safe mode tap position until one control cycle of 30 minutes has elapsed. After this period, tap changes will resume based on the measurements being received and once the system can make informed decisions once normal operation resumes.

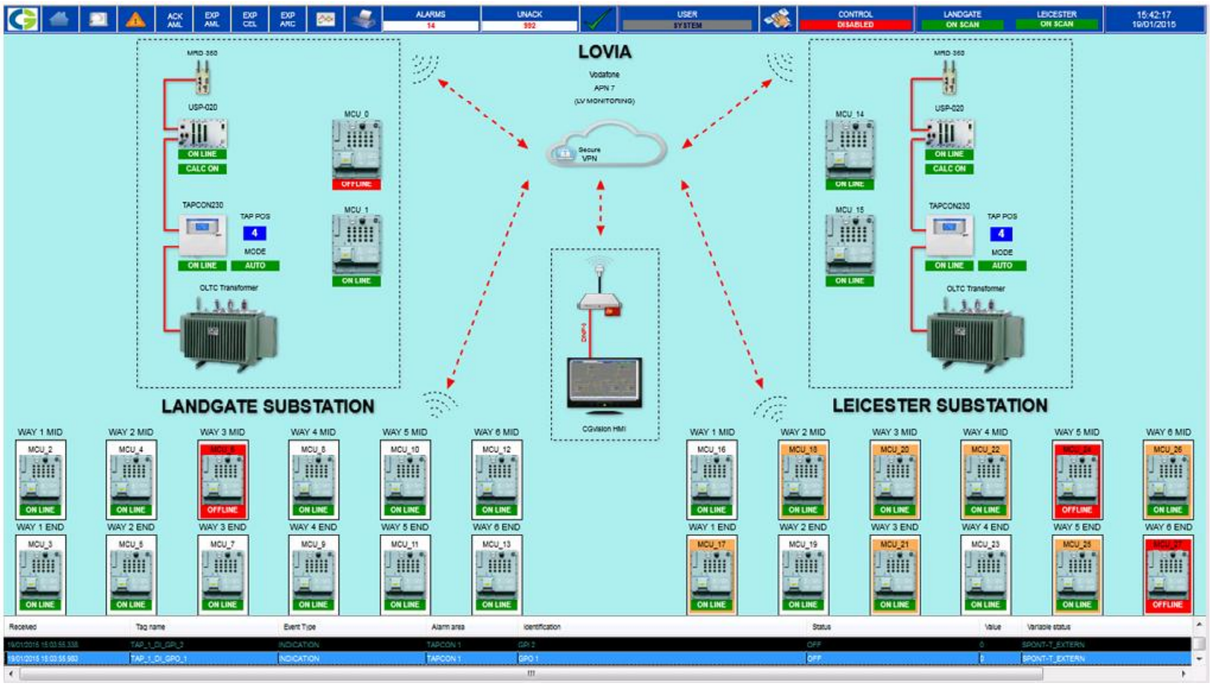
SCADA and Data Storage

All data from the system is transferred via the cellular network securely to within the ENW network. An archiving system stores metrology and status data as it arrives at one minute intervals. This data can be automatically exported in a number of formats for further analysis. Weekly CSV files were exported and provided to The University of Manchester for ongoing analysis and validation of the project.

Status information and metrology data critical to the performance of the system is displayed on an intuitive user interface known as CG Vision.

The system operates autonomously as a closed loop system, requiring no human interaction. However in certain circumstances it may be necessary to temporarily disable the system or take manual control over the OLTC. This can be done via the CG Vision user interface, which are summarised as follows.

Data points can be displayed in graphical form, which can be accessed via the CG Vision user interface.



CG Vision Human Machine Interface (HMI)

This image has been selected to illustrate the intuitive nature of the user interface, where traffic lights indicate the communications status. Detailed information can be obtained by clicking on any of the system element icons. Graphical displays, Alert and Status information and records can be accessed using the menus at the top left of the application.

Password protected manual control of the system is accessed using the icon at the upper right and by clicking on the controllable system element icons.

LANDGATE SUBSTATION
TAPCON 230
ON LINE
TAP Position
4
Input Mode
AUTO
USP Algorithm Calculations
ENABLED

MEASUREMENTS

Voltage Measured	103.3 V
Voltage Deviation	-1.4 V
Active Current	0.0 A
Reactive Current	0.0 A
Measured Current	0.0 A
Frequency	50.0 Hz

SETPOINTS

L1 Desired Voltage	105.0 V
L2 Desired Voltage	97.0 V
L3 Desired Voltage	101.5 V

ALARMS

Parallel Error	OFF
Local Remote Mode	ON
Over Voltage	OFF
Under Voltage	OFF
Over Current	OFF
Under Current	OFF
Status Alarm Relay	OFF

INDICATIONS

V1 Active	ON	Auto Input	OFF	GPI 1	OFF
V2 Active	OFF	Manual Input	OFF	GPI 2	OFF
V3 Active	OFF	Raise Input Active	OFF	GPI 3	OFF
Auto Active	ON	Lower Input Active	OFF	GPI 4	OFF
Paralleling Active	OFF	Negative Active Power Flow	OFF	GPI 5	OFF
Parallel Group 1 Active	OFF	Quick TAP Active	OFF	GPI 6	OFF
Parallel Group 2 Active	OFF	Rem Voltage Level Active	OFF	GPI 7	OFF
Parallel Master Mode Active	OFF	GPO 1	OFF	GPI 8	OFF
Parallel Follower Mode Active	OFF	GPO 2	OFF	Position Bit 0	OFF
Parallel Auto Sync Mode Active	OFF	GPO 3	OFF	Position Bit 1	OFF
Parallel Circ Current Mode Active	ON	GPO 4	OFF	Position Bit 2	ON
Raise Output in Operation	OFF	GPO 5	OFF	Position Bit 3	OFF
Lower Output in Operation	OFF	GPO 6	OFF	Position Bit 4	OFF
Parallel Status	OFF	GPO 7	OFF	Position Bit 5	OFF
Func Monitor	OFF			Position Bit Sign	OFF

Curve name	Color	Y axis	Active
TAP_1_AI_TAP_POSITION	🟥	☐	☑
TAP_1_AI_ACTIVE_CURRENT	🟥	☑	☑
TAP_1_AI_MEASURED_V	🟩	☐	☑
TAP_1_AI_FREQUENCY	🟧	☐	☑
TAP_1_AI_DESIRED_V_L1	🟩	☐	☑

CG Vision Manual Control of TC230 and Status

This screenshot shows the control and status screen for the Landgate TC230 and is accessed via clicking on the left hand TC230 icon. Once the access password has been correctly entered the TC230 and ultimately the OLTC can be controlled.

The CG Vision was set to automatically start-up, communicate with the RTU, archive and export data. In the event of a power failure or computer crash the SCADA system could be rapidly recovered.

Modelling

Simulated data is generated by UOM and run through the finished UOM algorithm within the modelling environment (Mathworks) and the results are saved.

The same simulated data is fed into the RTU to mimic Mid and End point metrology data from MCUs whilst the TC230 is connected to test equipment which can provide the same simulated voltage inputs as within the modelling environment.

The results from the real hardware are compared with the modelled result and any deviations over and above the expected measurement uncertainty are investigated. A correctly implemented algorithm should produce identical results to the model.

Approach to Integration and Verification

The development, integration and deployment of the project were run in a number of stages with ‘demonstrations’ required to be successfully completed prior to moving to the next stage of the project.

1. Communications Demo
    a. Test communications and verify data integrity
2. Automation Demo
    a. Phase 1 – Communications and remote manual control (Lab)
    b. Phase 2 – Installation, communications and remote manual control (Site)
    c. Phase 3 – Algorithm verification and system robustness (Lab)
    d. Phase 4 – Installation, system verification and system robustness (Site)
3. Monitor and Maintain
4. Analysis, verification and validation

The key aim of these stages was to gradually develop the system and prove essential aspects of the system gradually so that software bugs or hardware issues could be identified and rectified prior to the next stage. This approach de-risked further stages and allowed for deployment of the project as originally scheduled.

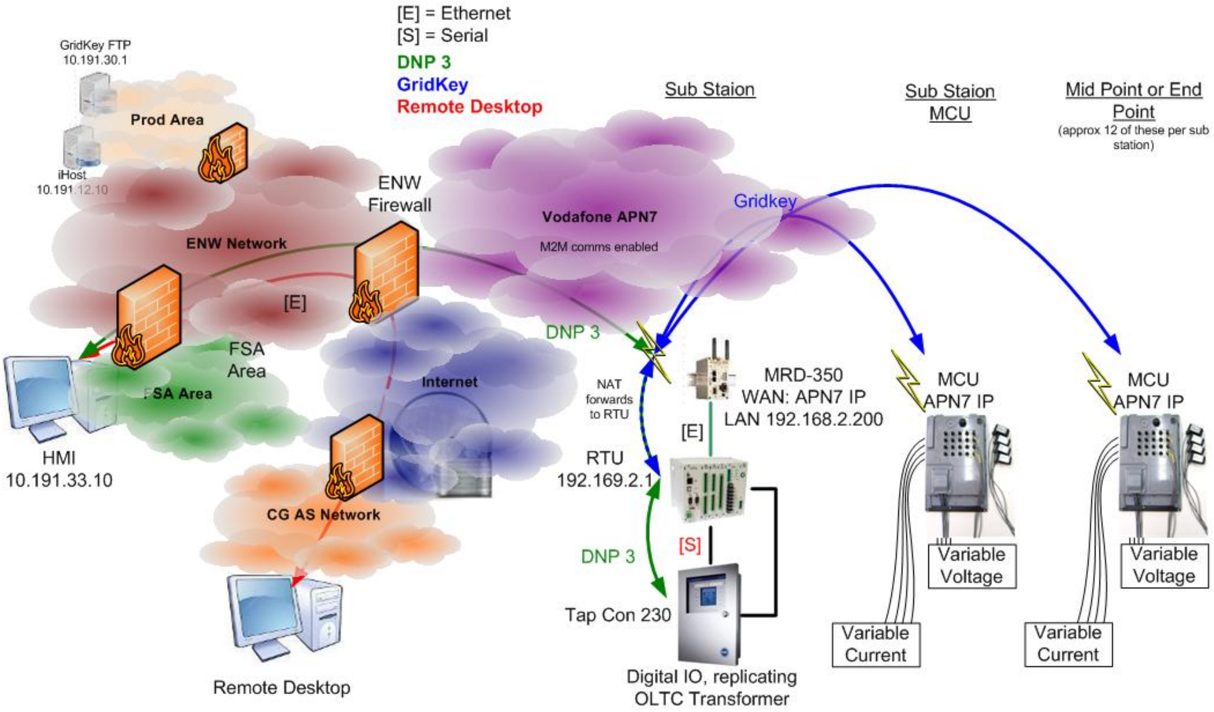
One key aspect to verify was the functionality of the algorithm within the RTU with real equipment in a realistic setting prior to deployment of the system on the electricity network to ensure there are no issues for connected consumers. It would have been highly disadvantageous to discover a latent defect in the system which caused unexpected and deleterious operation of the OLTC, resulting in an incident or customer complaints. Thus the approach detailed below was undertaken to minimise the risk of incorrect operation/behaviour of the system.

3. Automation Demo Breakdown

Phase 1 – Communications and remote manual control (Lab)

The intent of the Comms Demonstration was to demonstrate the ‘end to end’ communications between the different systems involved in the project and verify that sensible data is provided to and displayed by the visualisation software and sent to the data centre.

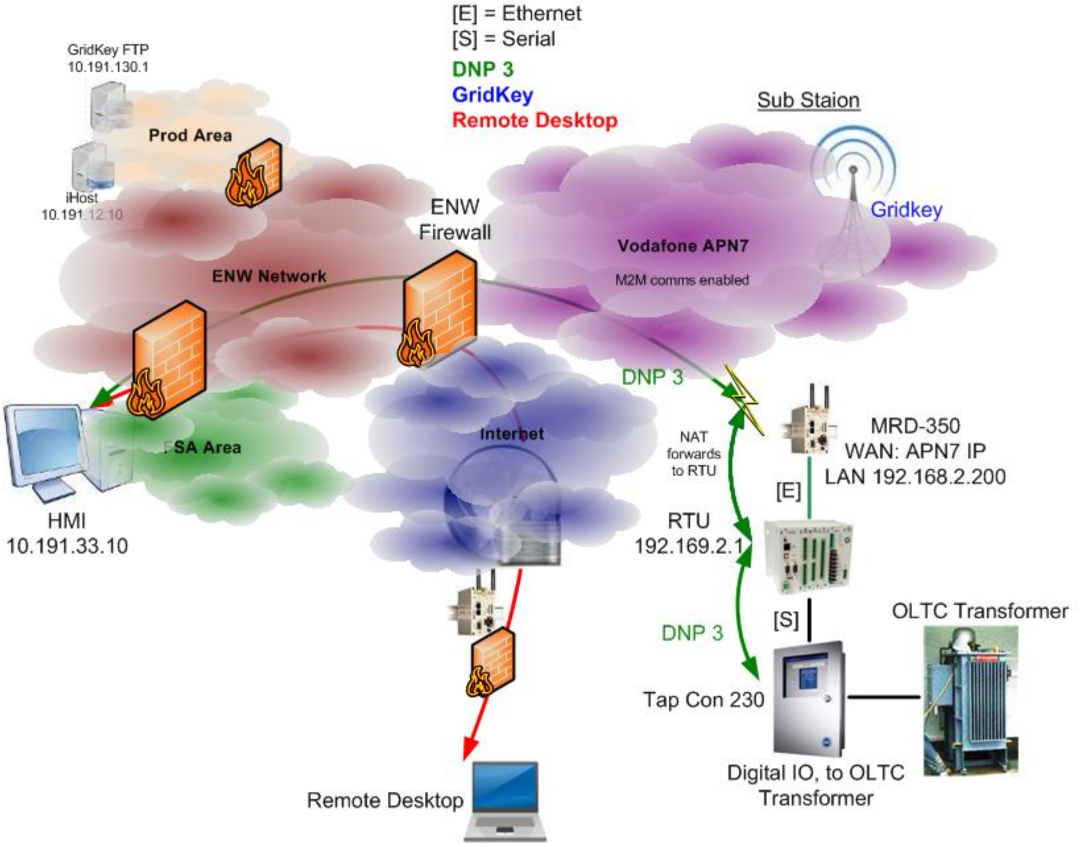
The system used GPRS communication between a number of mid and end points (approx. 12 per substation), the substation to which the feeders they monitor are connected and the HMI. The HMI software consisted of the CG Vision application and IP version of workbench which was run on an Electricity North West PC located at Linley House.



Phase 2 – Installation, communications and remote manual control (Site)

The intent of the Automation Demonstrations was to demonstrate that the OLTC can be controlled remotely by the CG Vision SCADA system and the algorithm was successfully implemented in the RTU and used to automatically control the voltages at the substation.

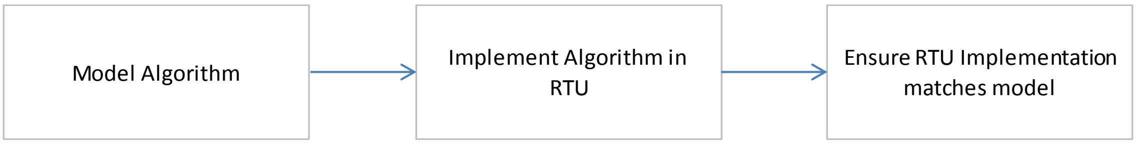
For the P2 automation demo MCUs did not communicate with the RTU and only the SCADA functionality is exercised (refer to diagram below)



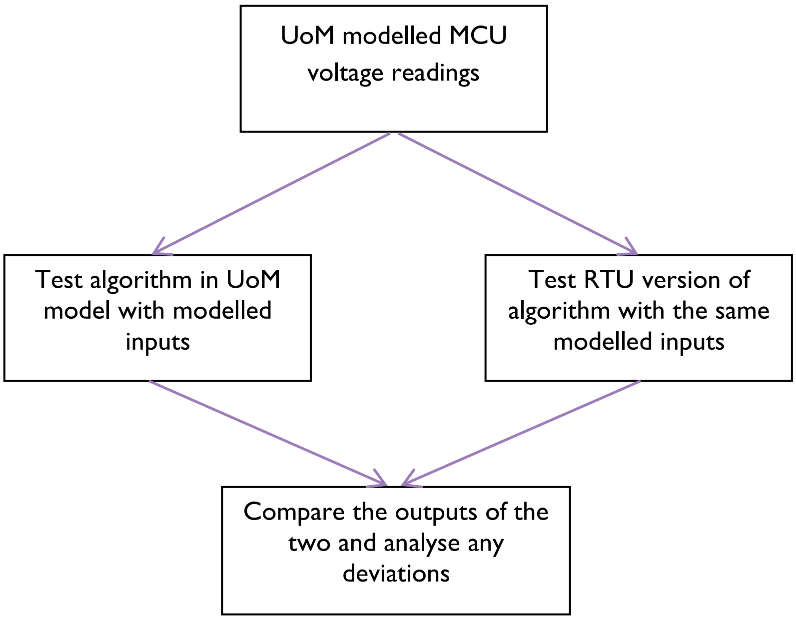
Phase 3 – Algorithm verification and system robustness (Lab)

The intent of Phase 3 was to demonstrate that the voltage control algorithm implemented in the RTU operates the Tap Con 230 in the same way as the UoM model & simulation predicts, and does not cause any unintended tap changes.

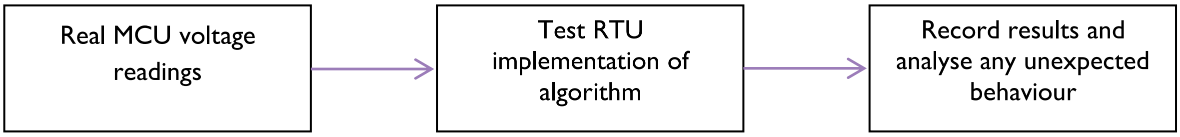
The diagrams below show the high level procedure for testing the RTU implementation of the voltage control algorithm. The purpose of testing in this manner is to ensure that the RTU implementation of the algorithm faithfully represents the UoM modelling of the algorithm.



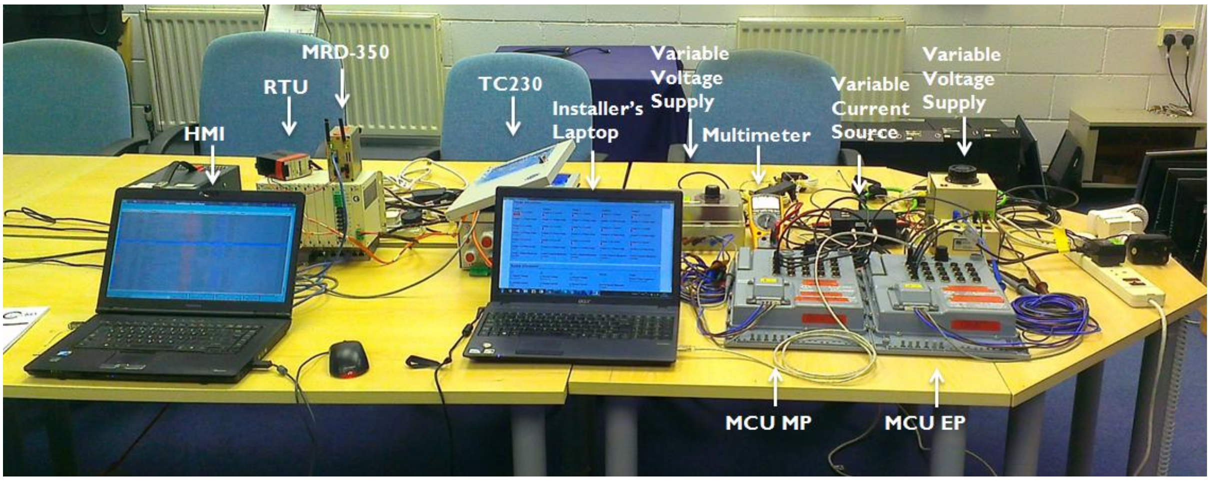
General procedure for generating and testing the voltage control algorithm



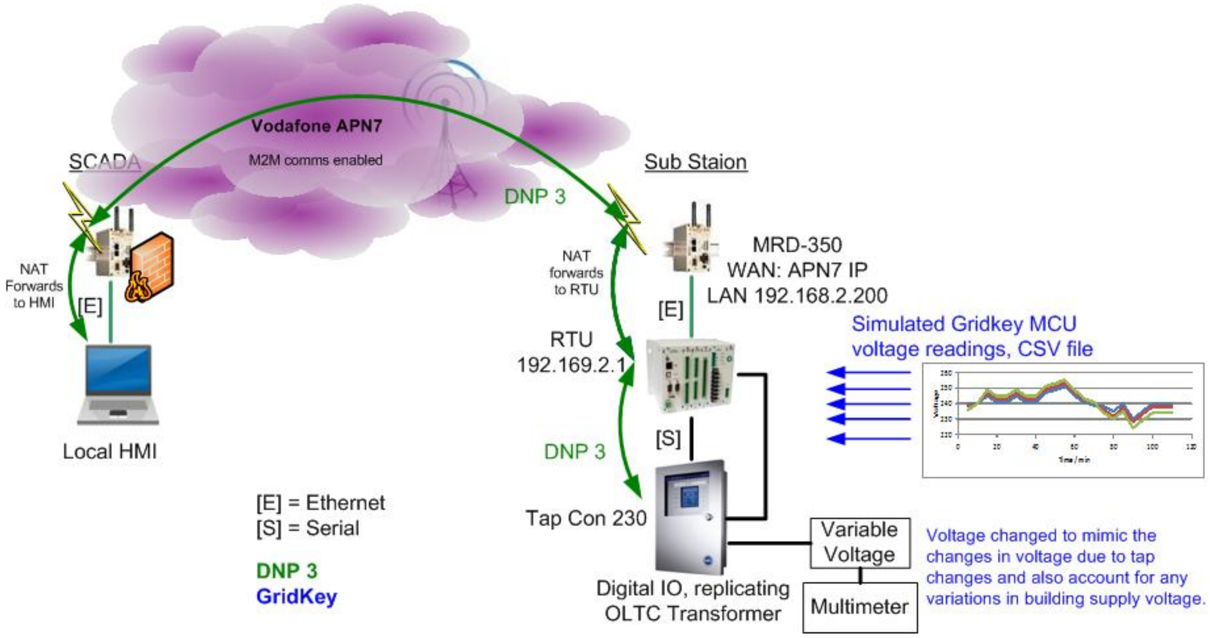
General procedure for verifying the voltage control algorithm operates as expected



General procedure for verifying the voltage control algorithm operates as expected with real data



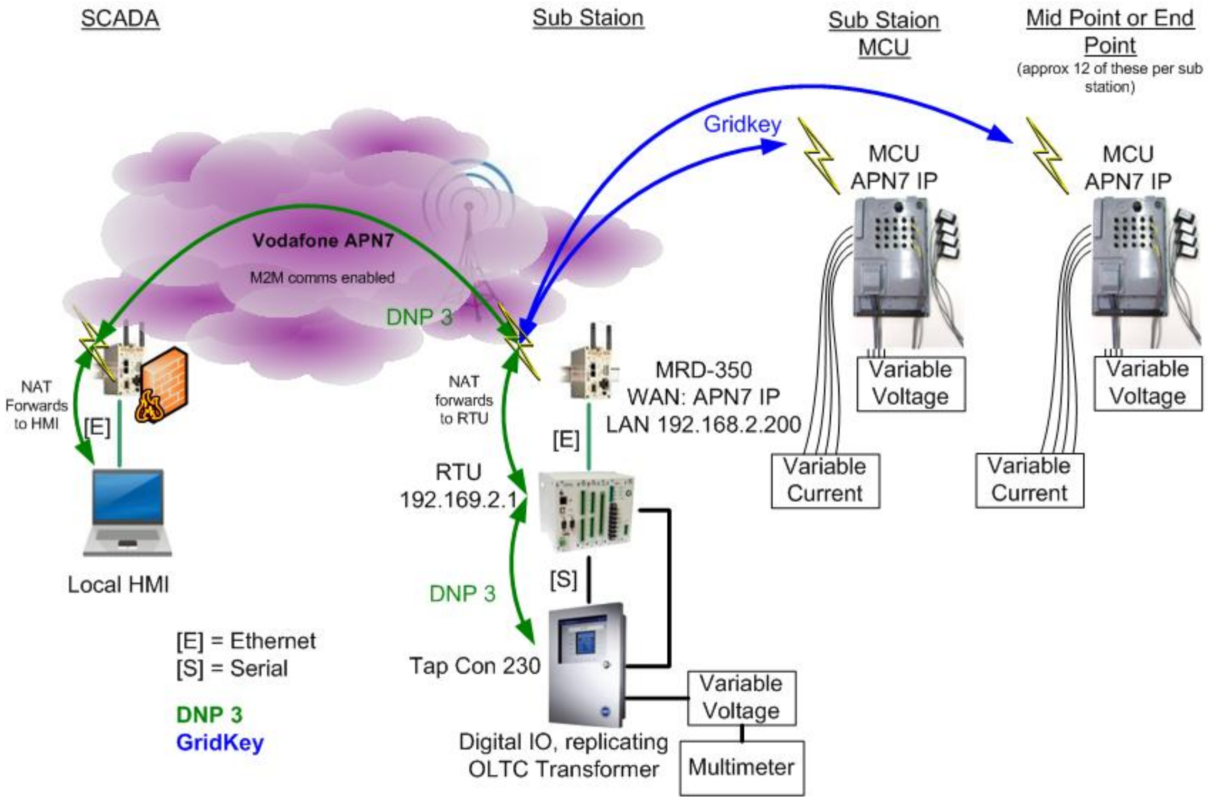
Phase 3 Algorithm Verification



Phase 3 Testing Part (a)

Following successful system testing with simulated metrology data, real metrology data was provided via MCUs connected to variable current and voltage sources. These could be varied as required to input the full range of voltages required to fully exercise the algorithm and test all transitions.

All interfaces for the system under test were deliberately made as similar as possible to the system which would be deployed and tested in the final phase of the automation demonstrations.

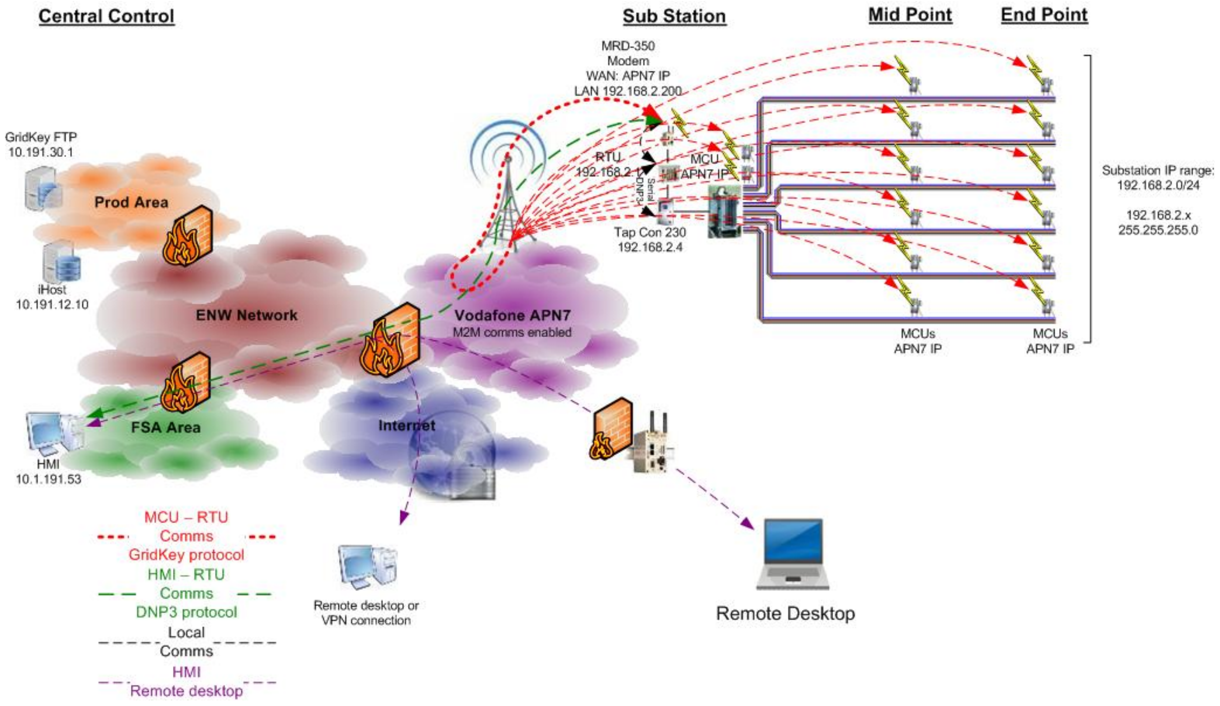


Phase 3 Testing Part (b)

Phase 4 – Installation, system verification and system robustness (Site)

The intent of the Automation Demonstration was to demonstrate that the OLTC could be controlled remotely by the CG Vision SCADA system and the control algorithm could also be successfully implemented in the RTU and used to automatically control the voltages at the substation.

The mid and end points provided voltage monitoring data to the substation controller (the RTU) which automatically controlled the OLTC to optimise the voltage along the feeders. The RTU provided status updates and monitoring data to the SCADA system, which was also able to manually control the OLTC in the substation if requested. The SCADA HMI software consisted of the CG Vision application and an IP version of Workbench which, as before, ran on an Electricity North West PC located at Linley House.



Monitor and Maintain

Upon completion of the Phase 4 Automation Demo, it was important to ensure the system continued to perform as expected. Given the trial nature of the programme, it was decided that for a limited period after the deployment of the automated control, daily periodic checks would be carried out.

4. Modifications

Using the more suitable SmartControl USP-020 rather than the other CG RTU

Avoiding use of the Thales NMS SCADA system. Integration with this system was judged to be too difficult. CG Vision provided a more flexible platform on which to develop an appropriate SCADA system for the LoVIA project.

Use of CG Vision to receive, archive and export all metrology and status data

Improved use of Model based design and hardware in the loop testing in order to verify correct functioning of the algorithm within the RTU when receiving real metrology data from MCUs connected to appropriate voltage sources. This reduced project risk and improved confidence of the system operation prior to deployment on the network.

5. Lessons Learnt

Data Server Storage and Power

The head end Server which stored the metrology data from the MCUs and status data from the RTU and Tap Con 230 was deliberately segregated from the ‘business as usual’ part of the network and associated equipment. However in doing so, this meant that the server did not have the same level of redundancy and backups as the production systems. At one point a power failure caused some loss of new data until power was restored (the rest of the system was unaffected). Additionally the volume of metrology data meant that either a large storage medium was required or regular removal of archive data was required. At one point the server’s storage space was exceeded and some new data was lost.

In order to ensure a complete record of detailed metrology and status data is maintained a server should have an uninterruptable power supply and a means of storing and backing up the large volumes of metrology data that arises from a project such as this.

The new GridKey data centre has been designed specifically to manage large quantities of data by using NoSQL database technology.

IP Architecture design

The specific IP architecture of the system is a very important factor in determining the scalability of the project for business as usual. The initial IP communications architecture would have made the LoVIA system more difficult to set up and more difficult to scale up. An alternative more scalable architecture was proposed and IP Security aspects reviewed in detail. This architecture proved to be less time consuming to set up and much more scalable, enabling the project to be rolled out much more widely if required.

Conflict between Instantaneous and Robust metrology

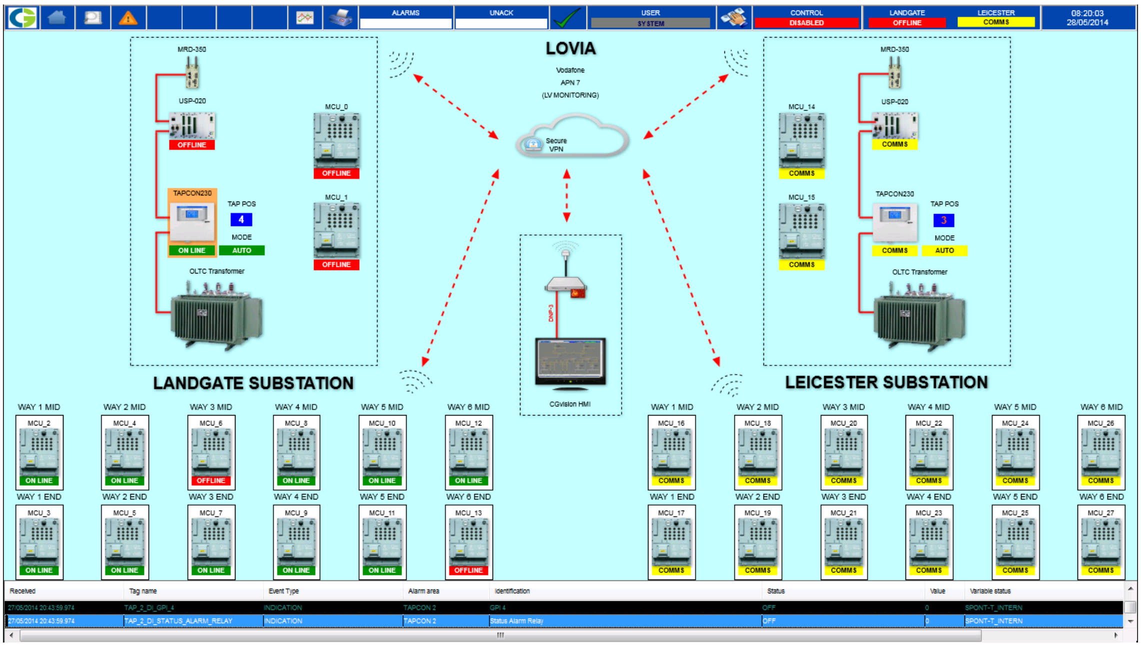
The metrology units are designed to robustly communicate all of the measured data to a server. That is without any gaps in data or corruption of data. This involves storing the metrology data locally on the MCU so that as signal strength drops and cellular communications data is not lost and when signal strength improves again the data can be sent. After a communications outage the units will send data to the server, the RTU in this case, in the order of oldest report first. If a large number of reports are queued to be sent, it may take some time before up-to-date reports are sent to the RTU.

However in order to control the system up-to-date data, data less than 30 minutes old, is required. The control algorithm has no need for the historic data used for monitoring, modelling and data analytics.

Clearly here there is conflict between the need to provide information required for real-time closed loop control and the information required for analysis, analytics and oversight of such a system. As a result Selex ES invested in updating the GridKey MCU design such that the most up-to-date data was provided first, with older data being transmitted at a lower priority in the background, after a cellular communications outage. This update resolves the conflict between the different use cases for the data provided.

External Antennas

The LoVIA system was proved to be, in general, robust to equipment failures and to communications issues. However the cellular modems within the substations represented a potential single point failure. Occasionally low signal strength caused the communications to drop out. Since the RTU no longer received data from the mid and end points the algorithm had no way of knowing what position to set the OLTC at so, as intended, reverted to the ‘safe tap position’ after an appropriate time. The substation modems were subsequently retrofitted with more effective external antennas which were sited in better locations. Fitting external antennas in this fashion increases the procurement cost slightly but reduces the likelihood of having to return to site due to communications issues.



Received	Tag name	Event Type	Alarm area	Identification	Status	Value	Variable status
27/05/2014 20:43:59.974	TAP_2_DI_GPI_4	INDICATION	TAPCON 2	GPI 4	OFF	0	SPONT-T_INTERN
27/05/2014 20:43:59.974	TAP_2_DI_STATUS_ALARM_RELAY	INDICATION	TAPCON 2	Status Alarm Relay	OFF	0	SPONT-T_INTERN

Substation Communications Failure

The above figure is a screenshot demonstrating the deleterious effects of a substation communications failure. In this case the signal strength to the cellular modems was too low and was alleviated via improved antennas and improved antenna placement. In this situation the substation cannot be remotely monitored or controlled by the SCADA system and the RTU cannot receive metrology data from the MCUs. If this situation persists the RTU instructs the TC230 to go to the designated safe voltage set point and the MCUs store the metrology data which will be transmitted once communications has been re-established.

Remote Access

Limited, secure remote access was provided to suppliers for certain elements of the system. In a number of cases this proved to be very useful in enabling suppliers to identify and rectify problems remotely as soon as they had been notified of an issue. This eliminated delays due to availability of staff and travelling time. For a system such as LoVIA where there are potentially complex interactions between different pieces of equipment, such access quickly allowed the different companies to work together to diagnose and resolve problems quickly and cheaply.

During on site testing and verification the system could be controlled by the ENW personnel immediately on site rather than requiring additional personnel to be available at the SCADA control room (to operate the system as instructed over the phone by on site engineers). Although strictly non-essential this speeded up the testing, and reduced the headcount and therefore costs associated with that activity.