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Low Voltage Integrated Automation (LoVIA)

A First Tier Low Carbon Networks Fund Project

Closedown Report

June 2015

CONTENTS

GLOSSARY

Bandwidth	The change in voltage required before a tap changer will operate.
CSC	Constant Set point Control. A form of controlling an on-load tapchanger where a target voltage is set and remains unchanged.
DNO	Distribution Network Operator.
DNP3	Distributed Network Protocol. A communications protocol used between components in process automation systems.
GPRS	General Packet Radio Service.
HMI	Human Machine Interface.
LCT	Low Carbon Technology.
MCU	Metrology and Communications Unit. A device to measure and transmit voltages and currents.
On Load tapchanger	A device which can alter the voltage output on a transformer. This device can be operated whilst the transformer is live.
Off Load tapchanger	A device which can alter the voltage output on a transformer. This device can only be operated whilst the transformer is NOT live.
RTU	Remote Terminal Unit. A microprocessor controlled electronic device which interfaces physical equipment with a control system.
Tap delay	This is the length of time the voltage needs to be outside the bandwidth before the tapchanger will operate.
TC	Time based Control. A form of controlling an on-load tapchanger where the target voltage changed depending on the time of day.
SCADA	Supervisory Control and Data Acquisition.

VERSION HISTORY

Version	Date	Author	Status	Comments
1	04/06/15	G Bryson	Issued	

1 EXECUTIVE SUMMARY

1.1 Aims

This project developed and trialled an integrated solution and novel application of automated voltage control of low voltage (LV) distribution networks. The project integrated existing and new equipment such as LV monitoring at mid / end points of feeders, distribution transformers with on-load tap changers and substation controllers. The integrated control solution delivered regulation of network voltages based on both local and remote real-time measurements. This allowed improved control of voltage profiles and facilitated the co-ordination of voltage regulating devices.

1.2 Methodology

Under the previous First Tier LCNF projects, "Voltage Management on Low Voltage Busbars" and "Low Voltage Network Solutions", Electricity North West had already deployed two distribution transformers with on load tap changers, automatic voltage control equipment, substation monitoring and cable monitoring.

LoVIA enhanced this existing equipment by deploying remote terminal units (RTUs) at the distribution stations. These RTUs were programmed with an algorithm, developed by the University of Manchester within the project, to control the tap changer based on the voltages from the remote monitoring points. The project also deployed equipment in the Electricity North West central control room to view and provide limited control for both installations.

In addition to analysing the outputs of the field trial, the University of Manchester produced models of the network and simulated a range of operating conditions to assess the benefits of this type of control against other types of control.

1.3 Outcomes

The project successfully developed an algorithm to provide voltage control based on remote measurements. This algorithm was successfully deployed in two distribution substations which already had transformers with on load tapchangers installed. The algorithm was encoded into a CG Automation Systems UK Ltd (CG) remote terminal unit which provided the interface to both the tap change control relay and the central control room.

The voltages required to drive the algorithm were measured by a Gridkey monitoring unit connected to the LV cables via a smart joint which was developed in the First Tier project, "Low Voltage Network Solutions".

The project also investigated various methods of communications between the devices. Following this investigation it was decided to use GPRS as it proved the most reliable method.

The University of Manchester developed models for the two substations and associated networks. These models were used to carry out a series of simulations to assess if voltage control in this form could offer advantages as the demand and generation mix changed in the future.

1.4 Key learning

This project has successfully shown that an integrated and coordinated voltage control system can be deployed at distribution substations to provide more refined management of voltages on the LV systems to support the connection of increased low carbon technology.

The project has shown the functionality of existing technologies such as an LV monitoring system and an on load tapchanger can be enhanced by the addition of a substation controller equipped with a control algorithm. The frequency of the control cycle has an effect on the quality of voltage delivered to the customer but this can be at the expense of tapchanger operation; ie the more frequent the control cycle the more tap changes per day which can lead to increased maintenance requirements. There appears to be an optimum cycle of around 30 minutes which minimises both the voltage issues and tapchanger operation.

The successful conclusions will be integrated into the Electricity North West network as part of the Second Tier project, Smart Street, which will deploy a centralised voltage control system operating on a 30 minute cycle.

1.5 Conclusions

Electricity North West has successfully deployed two trial systems which integrate new substation controllers with existing monitoring and tap change equipment to provide coordinated voltage control.

Through real time monitoring and the simulations carried out by the University of Manchester the project has shown that coordinated voltage control can be effective for LV networks. The frequency of the control cycle is an important factor and will impact both the voltage issues seen by the customer and the number of tap changes per day.

2 PROJECT BACKGROUND

This section reproduces the 'Problem' and 'Method' as stated in the original project registration.

The adoption at scale of low carbon technology such as Photovoltaic (PV), electric heating and vehicle charging can be shown to introduce significant challenges for DNOs when it comes to the control of network voltages. A number of innovative methods for managing these voltages are being explored as part of ongoing LCNF activities seeking to deploy new voltage regulating devices which afford network operators control over voltages. However, network analyses are revealing that the presence at scale of low carbon technology will result in varied voltage profiles even with a relatively small geographical area of a typical low voltage network. These varied profiles are expected to require the coordinated use of a number of different active voltage control devices. Such devices will include but are not limited to on-load distribution transformers and in-line voltage regulators. As such, these devices will need to form an integrated voltage control platform where the action if devices is appropriately coordinated. Low Voltage Integrated Automation (LoVIA) will seek to demonstrate the applicability of this control platform.

3 PROJECT SCOPE

The 'Scope' here is as stated in the original project registration.

LoVIA will bring together the GridKey LV monitoring solutions and the Electricity North West smart joint introduced within the Electricity North West LCN First Tier project – LV Network Solutions (ENWLT1003) together with CG Automation Xcell RTU (substation controller) which is already used on the Electricity North West Network and is integrated into the existing Network Management System to provide a single, integrated communications provision into the Electricity North West control system environment.

LoVIA will furthermore develop and modify a control algorithm running within the substation controller that will take the information provided by the LV network monitoring systems, both local and remote, and use this to control the action of an on-load tap change distribution transformer installed previously as part of the Electricity North West LCN First Tier project – Voltage Management on Low Voltage Busbars (ENWLT1002).

The scope of LoVIA is the deployment of two trial systems on the Electricity North West low voltage network. The objectives of which are to demonstrate the successful integration of new Distribution System equipment for the purposes of low voltage network coordinated voltage control.

LoVIA will provide the foundations of a future low voltage network coordinated voltage control platform and facilitate possible automated low voltage network operation.

4 SUCCESS CRITERIA

The following 'Success Criteria' are as stated in the original project registration.

The project will be considered a success following completion of:

- Demonstrate appropriate integration and communication between low voltage monitoring systems and a distribution substation controller (ie RTU)
- Show how LoVIA can be used to control the actions of an on-load tap change distribution transformer to control voltage
- Show through both field trial and simulation that coordinated voltage control will help network operators manage voltages following adoption of low carbon technologies.

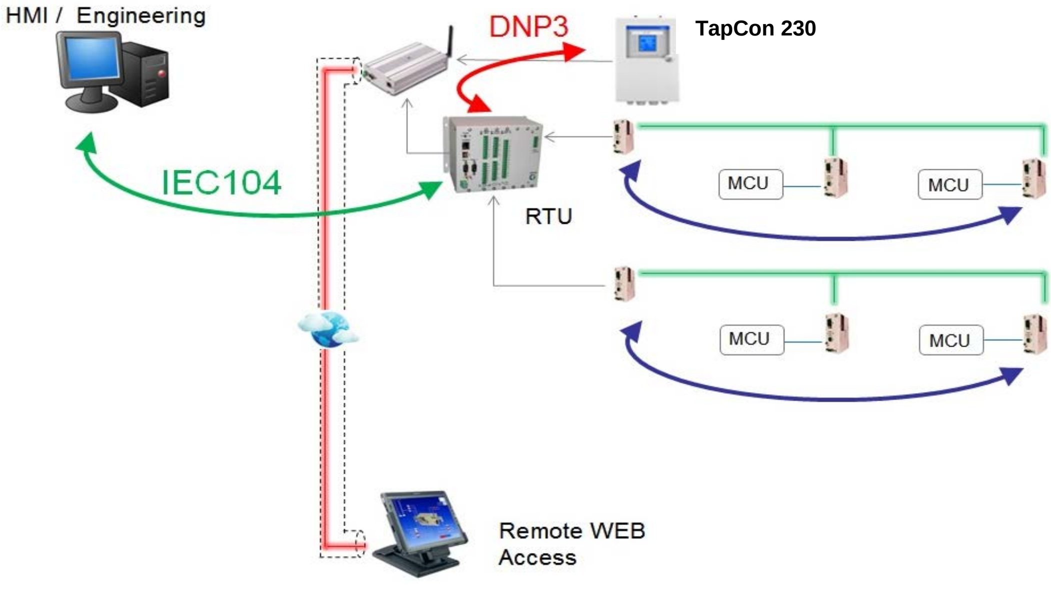
5 DETAILS OF WORK CARRIED OUT

5.1 LoVIA architecture

LoVIA integrated four separate components; an automatic voltage control algorithm developed by the University of Manchester, Gridkey metrology and communications units (MCUs) from Selex, a Tap Change Control relay from Reinhausen (TapCon 230) and a Human Machine Interface (HMI) from CG Automation Systems. All of these components were integrated using CG's Universal Smart-control RTU, USP-020. A schematic of the project's architecture is shown in Figure 1.

The remote monitoring MCUs are installed at the mid and end points of the LV feeders. The MCU sends monitoring data to the RTU located at the distribution substation. The RTU uses the voltage measurements as the input to an algorithm to calculate a new target busbar voltage. The target busbar voltage is then sent to the tap change control relay which in this case is the Reinhausen TapCon 230. All the data, including tap changer information, can be accessed by the HMI or a remote web access.

Figure 1: LoVIA project architecture



5.2 LoVIA implementation

The project demonstrated an LV autonomous control system operating in an area of high PV penetration. The system can also be monitored and controlled manually from the SCADA system if required. Metrology and status data is continually collected and stored.

To allow testing and development to continue while CG, Selex and University of Manchester developed the components, in parallel the Tapcon 230 and MCUs were simulated on the USP-020. A basic algorithm was developed to simulate the generation of set-points for voltage control. As each component was developed and tested the simulated elements were removed from the USP-020.

Bench testing of the system was carried out at the CG office in Jarrow and also at Electricity North West's office in Manchester before installation on the Electricity North West network at the trial substations. Full details of all the components and testing can be found in Appendix 1.

The System is made up of the following elements:

- Measurements
- 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.

5.3 Measurements

In order to make the correct control decisions at the substation, voltages along the feeders were required. This was achieved by installing MCUs at the mid and end points of each feeder using smart joints which were developed as part of the Electricity North West First Tier project, "Low Voltage Network Solutions". In LoVIA mid-point monitors were fitted, however it is recognised that voltages at the end of a feeder would be sufficient for the algorithm. If the system were rolled out as business as usual it is likely that only end point monitors would need to be fitted.

The MCUs presents the data as averages calculated over a one minute period. These measurements are then averaged to give the half hour value required by the algorithm. The MCUs report on a one minute period as it provides a much better visibility of the network during each algorithm cycle period, and allows the performance of the solution to be assessed. It also supports any changes to reduce the algorithm cycle period without reconfiguring the MCUs.

5.4 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.

For the overall project, GPRS cellular communications was considered the lowest risk and therefore the preferred technology. The MCUs communicated directly with the RTU via GPRS and the RTU communicated directly with the SCADA system GPRS. Within the substation the RTU communicated with the tap change control relay via a serial interface.

5.5 Voltage control

The on load tapchanger can adjust the transformer coil ratio whilst power is flowing through the transformer in a number of discrete steps. In this case there are nine steps, each with a 2% tap step.

A tap change control relay, in this case a Maschinefabrik Rheinhausen TapCon 230, is used to automatically change the tap position. In the LoVIA system a tap change can be achieved in a number of ways:

- Manually using push button control.
- Remotely via serial DNP3 from the RTU.
- Automatically based upon the voltage measured between phases L1 and L2.

As part of a previous Low Carbon Fund First Tier project, “Voltage Management on Low Voltage Busbars” capacitor banks were installed at the mid points of some feeders. These capacitors switched ‘in’ or ‘out’ based upon the voltage measured at the capacitor connection point. The operation of these capacitor banks in conjunction with the on load tapchanger was explored in detail by The University of Manchester and the results can be found in Appendix 2. For the purposes of the LoVIA trial, these capacitors were switched out so as not to affect the outcome of the project.

5.6 Automation

5.6.1 Control logic

The voltage control logic will change the busbar target voltage, considering voltages at the busbar as well as mid and end points. The measured data for the mid and end point voltages comes from the MCUs. However, for the busbar voltages the data measured by the TapCon 230 was used rather than the GridKey monitoring units at the busbar; this is mainly for consistency given that the TapCon 230 will ultimately control voltages based on its busbar measurements.

The target voltage, as a key input for the tapchanger, will be determined for every control cycle. Considering the busbar voltage as a reference, a compensating voltage (ΔV_i) for the control cycle i is calculated taking into account the measured voltages. The new set-point voltage ($V_{set\ i+1}$) is then obtained by the difference between the measured busbar voltage ($V_{busbar\ i}$) and the compensating voltage (ΔV_i), as shown in the equation below. This process takes place every control cycle (e.g., every 5 minutes, every 15 minutes, etc.).

$$V_{set\ i+1} = V_{busbar\ i} - \Delta V_i$$

To calculate the compensating voltage, three voltage zones have been defined as presented in Table 1. If voltages at the mid and end points are either higher than 253V or lower than 216V, they are in the red zone. When voltages are between 248 to 253V and between 216 to 221V, then they are considered to be in the orange zone. Finally, voltages between 221 and 248V correspond to the green zone. The latter is the ideal zone.

Table 1: Compensating voltage factor according to the voltage zones

		Maximum				
		Red >253V	Orange 253V≥. ≥248V	Green 248V>. ≥221V	Orange 221V>. ≥216V	Red <216V
Minimum	Red >253V	+3				
Minimum	Orange 253V≥. ≥248V	+2	+2			
Minimum	Green 248V>. ≥221V	+2	+1	0		
Minimum	Orange 221V>. ≥216V	+1	0	−1	−2	
Minimum	Red <216V	0	−1	−2	−2	−3

By determining how far the measured voltages, in particular the maximum and minimum values, are from the ideal range (i.e., the green zone) it is possible to estimate the required compensation of the busbar voltage based on the number of tap steps required to bring the voltages within limits. Table 1 shows the factor that should be multiplied by the voltage of one tap step to give the compensating voltage.

For a given control cycle i, the voltage zones of the maximum and minimum of all the mid and end point voltages are determined. The compensating voltage (ΔV_i) is then obtained by multiplying the corresponding factor in Table 1 by 4.6V (which is equal to the 2% tap step of the transformers in this trial). Further detailed information can be found in the University of Manchester reports in Appendices 3 and 4.

5.6.2 Safe Mode

In order to ensure any connected consumers were not adversely affected by the system a Safe Mode was implemented to allow the system to enter a predefined state when there is inadequate data for the algorithm to make decisions, eg communications failure with MCUs.

Safe Mode causes the system to go to a defined tap position and freeze taps until the conditions have changed sufficiently for the algorithm to operate effectively. At that point the system will exit Safe Mode and resume normal operation.

The Safe Mode tap position is equivalent to a substation line to neutral voltage of 240V assuming a primary voltage of 11kV.

For LoVIA conditions which implemented safe mode are:

- Loss of 25% or more of the measurements due to a communications error
- Voltage readings out of range – defined as any voltage outside 180V to 260V inclusive.

5.7 SCADA and data storage

All data from the system is transferred securely via GPRS to a server in the Electricity North West control room. An archiving system stores the data as it arrives at one minute intervals and it can be exported in a number of formats for further analysis. Files were exported weekly and provided to The University of Manchester for analysis and validation of the project.

Data critical to the performance of the system is displayed on the user interface, CG Vision. CG Vision provides the facility to remotely operate the tapchanger as well as display any of the data in graphical form. CG Vision was set to automatically start, communicate with the RTU, archive and export data in the event of a power failure.

Figure 2: CG Vision Human Machine Interface (HMI)

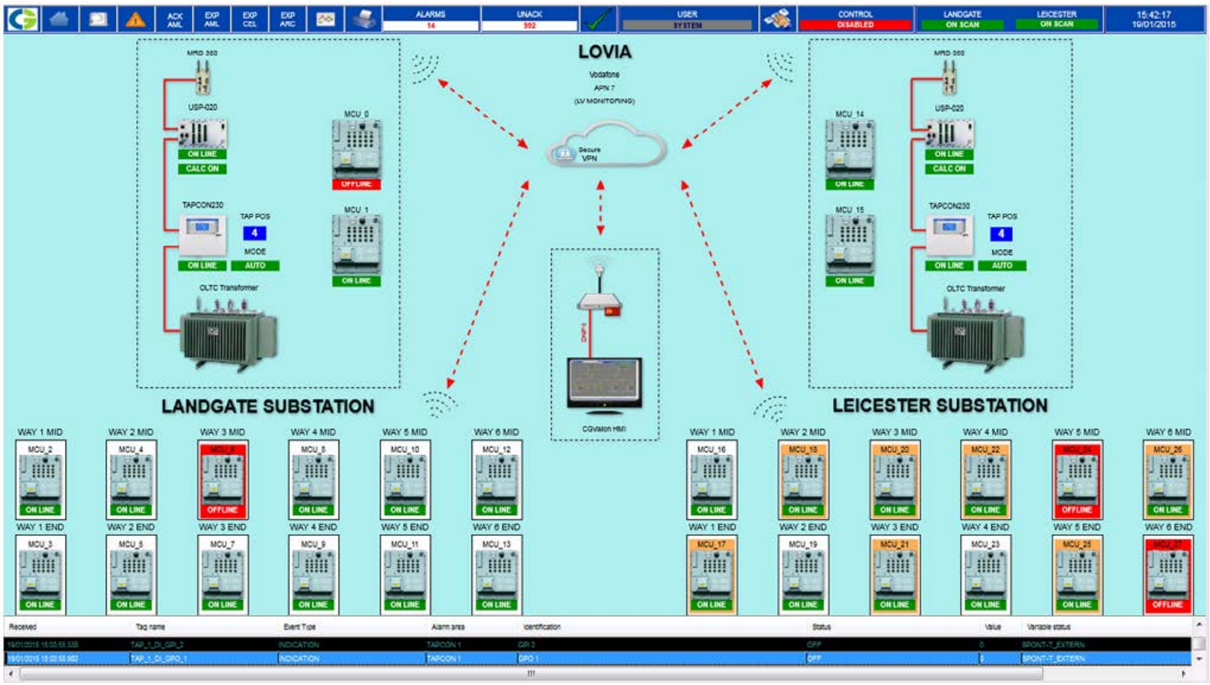


Figure 2 shows the intuitive nature of the user interface, where traffic lights indicate the communications status. Detailed information can be obtained by clicking on any of the system element icons. Graphical displays, alerts, status information and records can be accessed using the menus at the top left of the application.

Figure 3: CG Vision Manual - Control of TapCon230 and Status

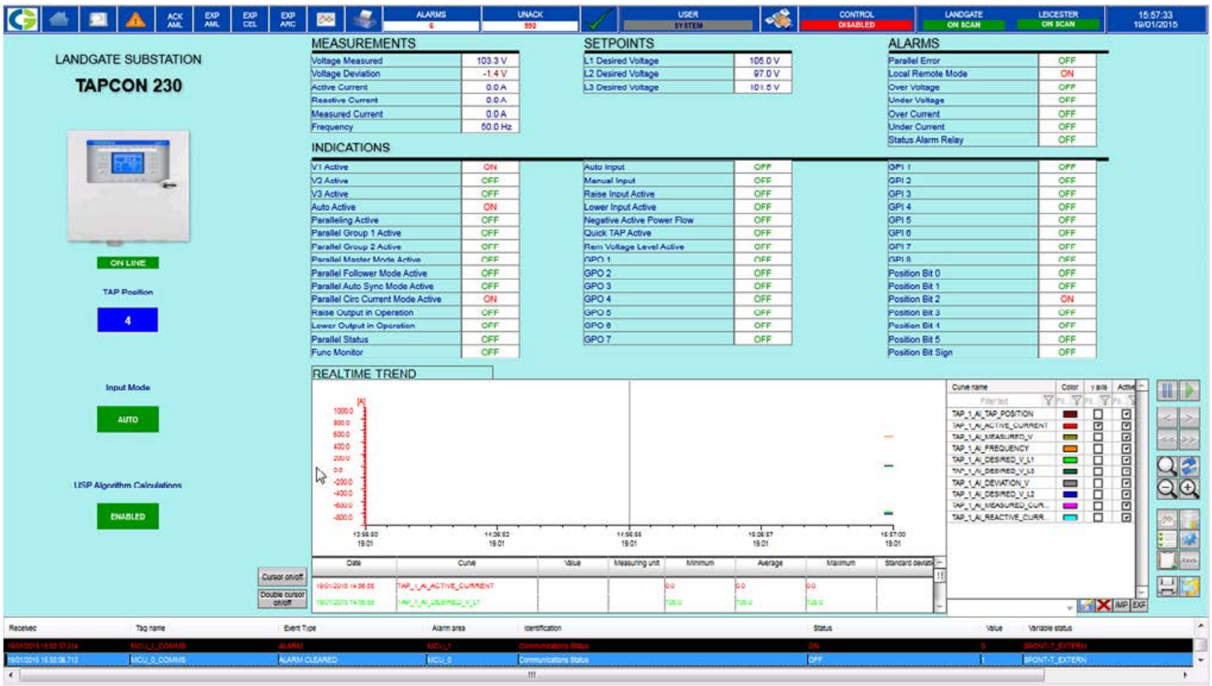


Figure 3 shows the control and status screen for one of the tap change control relays. Passwords must be provided to remotely control the device.

5.8 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.

- Communications demo
  - Test communications and verify data integrity
- Automation demo
  - Phase 1 – Communications and remote manual control (Lab)
  - Phase 2 – Installation, communications and remote manual control (Site)
  - Phase 3 – Algorithm verification and system robustness (Lab)
  - Phase 4 – Installation, system verification and system robustness (Site)
- Monitor and maintain
- 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.

6 PROJECT OUTCOMES

6.1 Comparison of the LoVIA control algorithm with other control strategies

The performance of the LoVIA control algorithm is examined by comparing with other control strategies that could be used in LV networks. Therefore, this project has devised another two different on-load tapchanger based control strategies, including constant set-point and time-based control. The benefits of adopting transformers fitted with on-load tapchangers, particularly in comparison with the off-load tap changer, are assessed through week-long Monte Carlo-based analyses considering all PV penetrations and seasonality (i.e., summer, spring/autumn and winter).

These corresponding voltage control strategies are:

- **Off-Load Tap Changer**. To cope with PV systems, the off-load tap changer is set to tap position 4, i.e., +2.5%.
- **Constant Set-Point Control (CSC).** The set-point is kept at a fixed value of 1.04 pu throughout the year.
- **Time-Based Control (TC)**. The set-point is changed according to the time of the day. During minimum demand a set-point voltage of 1.03 pu is considered whereas during peak this value is set to 1.05 pu. Daily schedules are slightly modified per season to account for daylight hours.

The season-weighted average performance metrics, ie voltage compliance and the number of tap operations, are presented in figures 4 and 5 respectively. For the LoVIA control strategy, three different control cycles, ie 5, 15 and 30 minutes, are used.

As seen in figure 4 with the off-load tap changer, customers experience voltage issues from 30% of PV penetration on the assessed network. With a 70% penetration, one in four customers in the network could experience voltage issues. However, with the on load tapchanger, disregarding the control strategy, it is only after 50% of PV penetration that customers might experience voltage problems. Although the Time-Based Control (TC) strategy results in a better mitigation of voltage issues than Constant Set-Point (CSC) and comparable with the LoVIA control, this is mostly done at the expense of more tap operations. Overall, the LoVIA 30 minute control strategy resulted in a much better mitigation of voltage issues than TC and CSC and with only a fifth of the tap operations, as shown in Figure 5.

Figure 4: Customers with voltage problems – comparison (annual average)

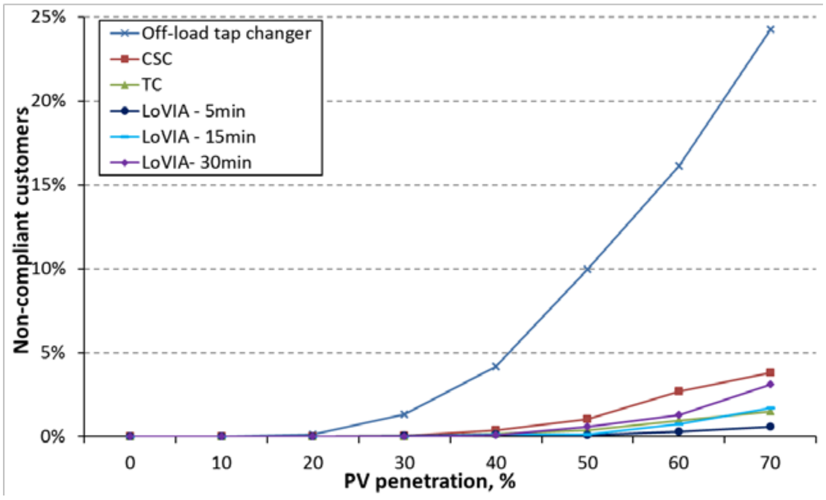
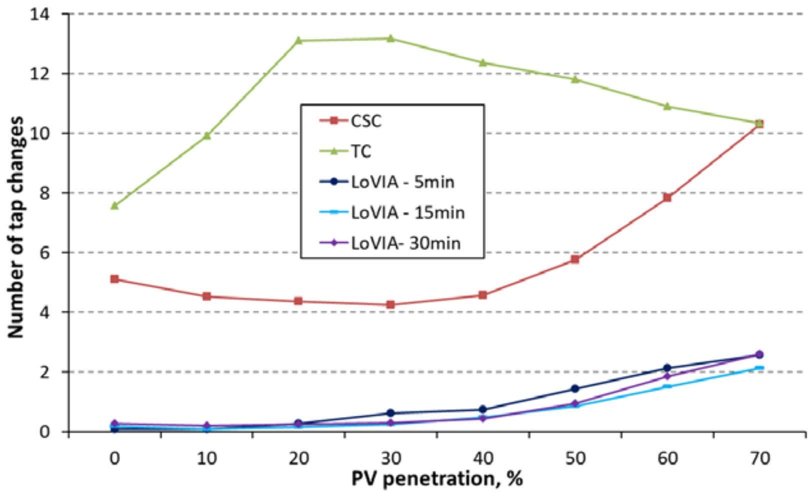


Figure 5: Daily average number of tap changes – comparison (annual average)



It is concluded that the LoVIA is the best control strategy among the three. However, for networks without remote monitoring, CSC and TC can still deliver benefits. DNOs can choose the most suitable control strategy depending on the characteristics of their networks and the focus of the operation, e.g., targeting voltage compliance or fewer tap operations.

6.2 Performance of the deployed LoVIA logic

The LoVIA strategy was commissioned in the transformers with on load tapchangers at Landgate and Leicester Ave substations on 13th and 14th May 2014, respectively.

The TapCon230 relay parameters were set to:

- Bandwidth 2.2%
- Tap delay 120 seconds

The LoVIA control cycle was set to 30 minutes.

The data of the tap position and the monitoring voltages at the busbar as well as the mid and end points of the LV feeders were recorded and extracted from the corresponding HMI.

The behaviour of the transformers at Landgate and Leicester Ave are shown in figures 6 and 8. The blue line represents the measured busbar line-to-line voltage, which is obtained from the TapCon 230. It should be noted that this measurement is the actual voltage divided by 4 due to the measurement circuit within the relay.

When using the LoVIA logic the set-point follows the trend of the busbar voltage as shown in figures 6 and 8. For a given set-point, an actual tap change only occurs if the voltage varies by more than the bandwidth setting for longer than the tap delay.

Figure 6: Actual tap operation at Landgate Substation

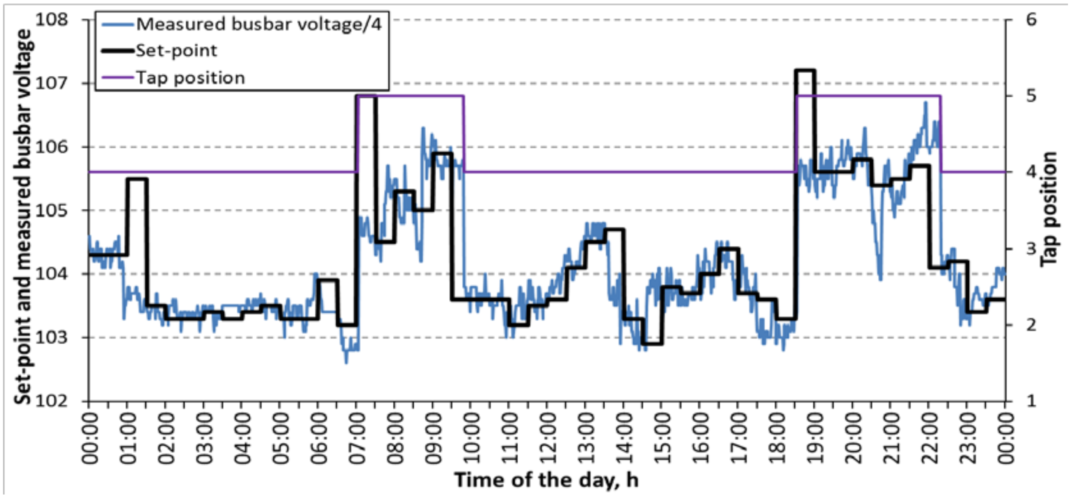


Figure 7: Measured voltages at Landgate Substation

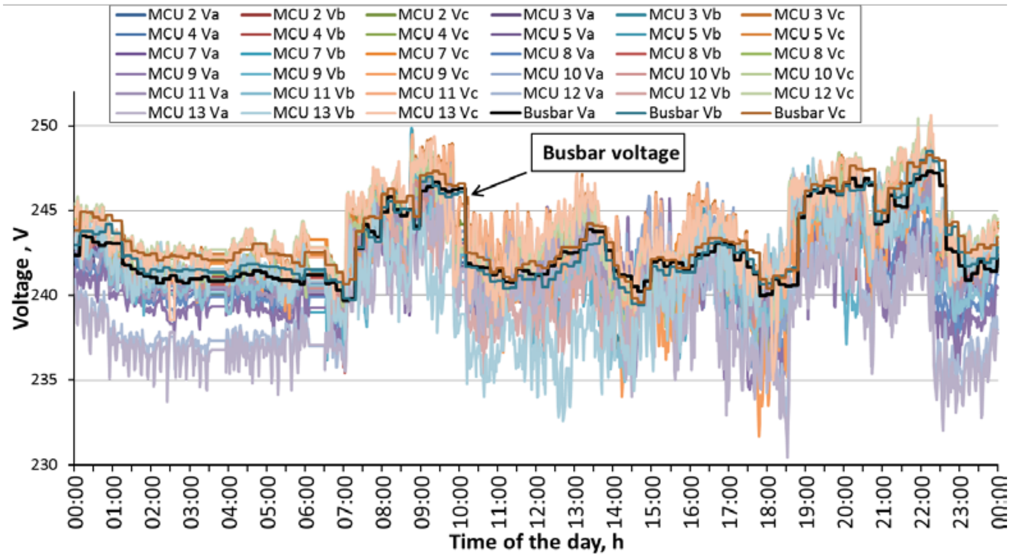


Figure 8: Actual tap operation at Leicester Ave Substation

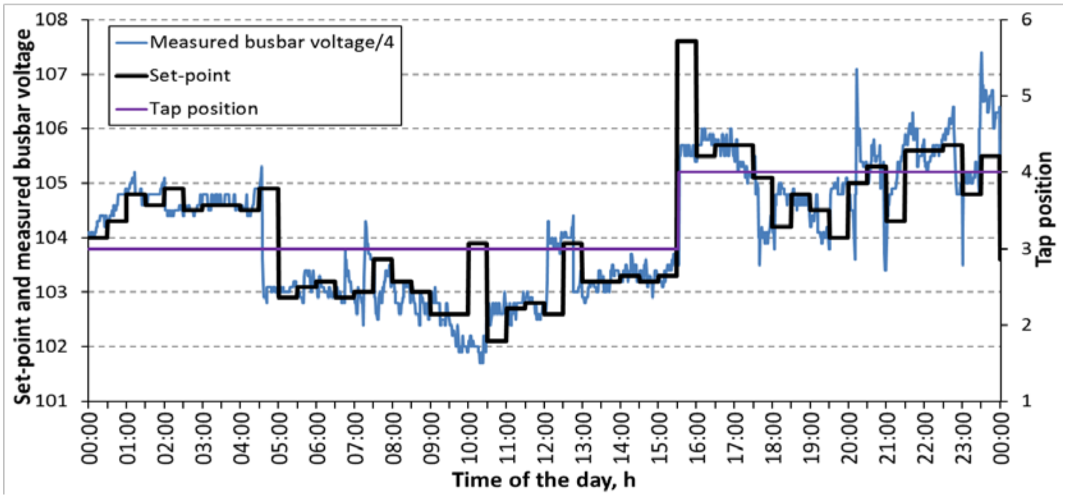


Figure 9: Measured voltages at Leicester Ave Substation

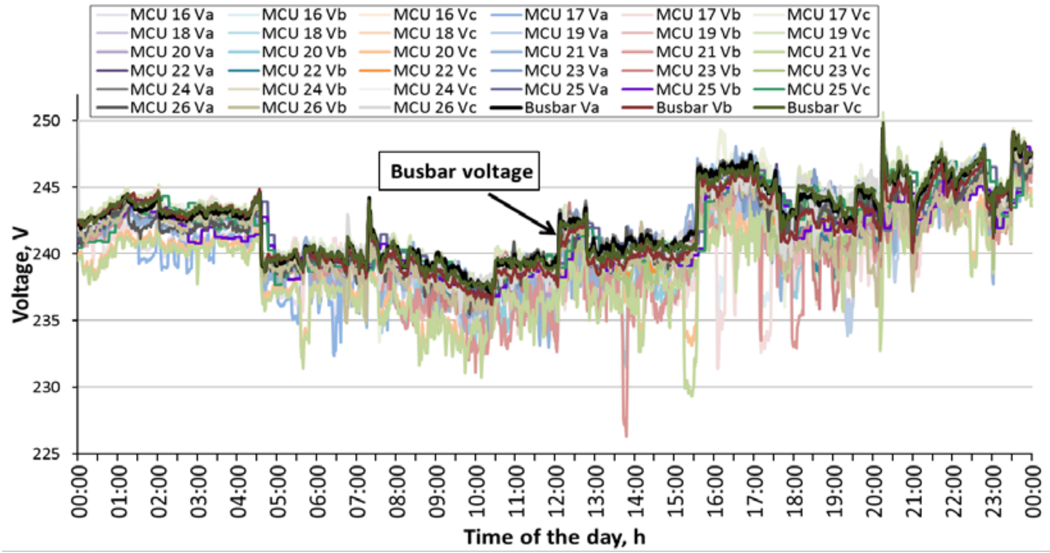


Figure 7 presents the measured voltages at the busbar as well as the mid and end points for Landgate; MCUs 2 to 13 correspond to the monitoring at the mid and end points of the 6 LV feeders (data for MCU 6 was not available). Similarly, figure 9 presents the measured voltages for Leicester Ave; MCUs 16 to 27 correspond to the monitoring at the mid and end points of the 6 LV feeders (data for MCU 27 was not available).

From figure 7 it can be seen that when household demand started to increase at 07:00, the deployed LoVIA logic increased the set-point. As a result, as shown in figure 6, the tapchanger operated to increase the voltage on the LV feeders. When the net demand decreased (due to PV generation and/or lower demand), the set-point was lowered, operating the tapchanger back to position 4 at 09:30. A similar process happened in the evening (18:30 to 22:00) when demand increased.

For Leicester Ave (figure 8), the tapchanger only operated once (from position 3 to 4) at 15:30 when the household demand increased. From this, it can be said that (for the two networks with PV penetration of approximately 30%) tapchanger operation mainly occurs in response to variation in household demand rather than variation in PV generation.

Analysis of the data showed that the LoVIA algorithm successfully managed the LV voltages on all feeders without the need to go into Safe Mode. The analysis also showed that there 50 tap changes (1.4 per day on average) at Landgate and 136 at Leicester Ave (1.9 per day on average). Full details of the university analysis can be found in Appendices 5 and 6.

The overall on site performance was aligned with the simulation work completed by the University of Manchester. Therefore, it can be concluded that the LoVIA control strategy has performed as expected in the two networks.

7 PERFORMANCE COMPARED TO AIMS

7.1 Demonstrate appropriate integration and communication between low voltage monitoring systems and a distribution substation controller (ie RTU)

This project has successfully reconfigured existing remote monitoring systems to send their data to a newly deployed substation controller (RTU). The data seen by the RTU is visualised on the HMI which is located in the Electricity North West control room.

The RTU is connected to the distribution transformer tap change control relay via serial communications and connected to the control room server via GPRS. This integrated system allows remote operation of the distribution transformer tapchanger from the central control room.

Local operation of the device can be either automatic via the LoVIA algorithm or manually using push button control.

7.2 Show how LoVIA can be used to control the actions of an on-load tap change distribution transformer to control voltage

This project successfully deployed an algorithm developed by the University of Manchester within the substation controller RTU. This algorithm uses the data from the remote monitoring systems and delivers a new voltage set point to the tap change control relay. The results presented in section 6 and appendices 5 and 6 demonstrate the benefits of using this algorithm to control the voltages. Figure 5 in section 6 clearly demonstrates the benefits of the LoVIA control algorithm - over both an off load tapchanger and a constant set point on an on load tapchanger - in terms of voltage quality delivered to customers.

7.3 Show through both field trial and simulation that coordinated voltage control will help network operators manage voltages following adoption of low carbon technologies

LoVIA successfully trialled co-ordinated voltage control at two distribution substations. The University of Manchester used these trial networks and successfully simulated increasing penetrations of distributed generation. The results from the trial and simulations are presented in section 6. These results clearly show that voltage issues will increase as the penetration level of PV increases unless DNOs look at actively controlling voltages.

The project has shown that by using co-ordinated voltage control LV networks can accept significantly more low carbon technologies without the need for reinforcement.

8 REQUIRED MODIFICATIONS

The only modification from the registration document was in the type of RTU deployed at the distribution substation.

CG Automation recommended the use of their SmartControl USP-020 rather than the Xcell RTU referred to in the registration document. The Xcell RTU is widely used within Electricity North West and is aimed at grid and primary installations. The USP-020 is a more compact unit and is more suited to a distribution substation environment.

9 VARIANCE IN COSTS AND BENEFITS

9.1 Cost variance

The original project budget was £550k but the final cost of the project was £769k. From the breakdown in the table below it can be seen that most of the elements delivered with significant cost variances. The reasons for the variances are described here:

Item 2: Internal technical support was not originally forecast. This was an oversight which has been corrected in future projects. The technical support involved approval of equipment, installation procedures and providing technical expertise to academia.

Item 3: The cost variance was materials procurement was as a result of the RTU change described in the required modification section and additional internal installation costs.

Item 4: Additional internal IT support was required to set up the software and communication links to site.

Item 5: To assist with the installation it was necessary to use the services of an external contractor which kept the project on plan.

Item	Category	Estimated Costs £k	Final Costs £k rounded	Variance (%)
1	Programme & Project Management	81	84	3.7
2	Project Technical Support	0	123	100
3	Materials Procurement, Testing and Installation	335	393	17.3
4	IT - Software licence, monitoring & support	9	27	200
5	Research Support, including academic / consultancy / contractor	125	142	13.6
	Total	**550**	**769**	

9.2 Benefit variance

There is no benefit variance associated with this project as it successfully delivered on all the benefits predicted in the project registration.

LoVIA successfully deployed a co-ordinated voltage control system for the LV network. The analysis of the system performance clearly demonstrated that the control of voltages can realise significant voltage headroom allowing the connection of more low carbon technologies.

10 LESSONS LEARNT

Following on from the First Tier Projects "Voltage Management on Low Voltage Busbars" and "LV Network Solutions" this project has successfully integrated the LV monitoring system and an on load tapchanger via a distribution substation controller. This project built on previous learning and recommendations to consider the control methodologies for these technologies.

LoVIA offers a local control solution to the anticipated voltage issues caused by the connection of Low Carbon Technologies. A further extension to this and the previous projects is Electricity North West's Second Tier project, Smart Street. This project will combine the learning gained in the LoVIA project on voltage control with new network configurations and a central control system. This will result in a central control solution to the same problem.

Using the learning from this project and the associated First and Second Tier Low Carbon Networks Fund projects, Electricity North West plans to carry out a detailed review of the LV planning codes of practice. This should result in more comprehensive guidance with a wider portfolio of solutions to cater for different network conditions.

As part of the project the University of Manchester has made available the logic for the algorithm (Appendix 2 of this report) which can be implemented in other manufacturers' substation controllers.

Electricity North West has presented this project at two LCNF annual conferences. Further details on this project including all of the academic reports will be available on the Electricity North West website.(www.enwl.co.uk/thefuture)

During the course of the trial there were a number of learning points which were deemed significant enough to detail in the section below. DNOs may find these of interest and applicable to other projects.

10.1 Server power and storage

The server, located in the Electricity North West control room, 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 backup as the production systems. During the trial there was a power failure at the control room which resulted in the loss of data until power was restored (the rest of the system was unaffected).

The volume of measurement data meant that either a large storage medium or regular removal of data was required. During the trial, the server's storage space was exceeded and some data was lost.

In order to ensure a complete record of detailed measurement and status data is maintained the server should have an uninterruptible power supply and a means of storing and backing up the large volumes of data.

10.2 Conflict between data requirements

The MCUs are designed to robustly communicate all of the measured data to a server which involves storing the data on the MCU so that as signal strength drops, data is not lost and can be sent when signal strength improves. After a communications outage the MCU will send data in chronological order. In order to control the system the latest data is required and the algorithm has no need for the historic data used for data analytics.

Clearly there is conflict between the need to provide the data required for real-time control and the information required for analysis. As a result Selex ES updated the MCU to provide the most up-to-date data first, with older data being transmitted at a lower priority in the background.

11 PLANNED IMPLEMENTATION

As stated previously Electricity North West intends to implement the learning from this project through the Smart Street project.

Electricity North West has learnt that control of voltages can realise significant voltage headroom allowing the connection of more low carbon technologies. It is also recognised that this control can be carried out locally as per LoVIA or centrally as will be deployed in Smart Street.

This control of voltage is important as voltage is often the first issue for the future implementation of LCTs as confirmed by the First Tier "Low Voltage Network Solutions" project. It should be noted that this applies not just to Generation but also to Heat Pumps and Electric Vehicles.

Electricity North West plan to carry out a detailed review of the LV planning codes of practice following all these projects. This should result in more comprehensive guidance with a wider portfolio of solutions to cater for different network conditions which can be used as part of business as usual.

12 FACILITATE REPLICATION

The objective of this project was to field trial an integrated voltage control scheme to understand its potential to help with anticipated future challenges associated with the connection of low carbon loads. The trials were used to investigate the benefits (or otherwise) of using coordinated control to manage voltages on the LV network.

As a direct outcome of this project Electricity North West has produced and made publicly available:

- The algorithm used to adjust the setpoint, and
- A communications architecture for the LoVIA system

This information is contained both in this report and in the appendices and will be made available for download via the Electricity North West website. (www.enwl.co.uk/thefuture)

The specification, installation and other details for the monitoring system and the on load tapchanger can be found in the First Tier close down reports for the forerunner projects.

All installation and commissioning work for this project was carried out using the standard Electricity North West policies and procedures.

The reports from the University of Manchester provide details on the different control methodologies which can be used and the associated benefits. DNOs can use this as a basis as to which control methodology is suitable for its network. These reports will be made available on the Electricity North West website.

13 APPENDICES

1. Selex and CG Automation Report
2. Deliverable 1.2 &1.3 "OLTC and Capacitor Bank Simulation – University of Manchester
3. Deliverable 1.1 "Model Creation and Control Logic" – University of Manchester
4. Deliverable 1.1 "Model Creation and Control Logic – Appendix 1" – University of Manchester
5. Deliverable 2.1 "Scenario Analysis" – University of Manchester
6. Deliverable 2.2 "Guidelines, Benefits and Limitations" – University of Manchester