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NIA-ENWL011

Enhanced Automatic Voltage Control

Closedown Report

31 July 2019

VERSION HISTORY

Version	Date	Author	Status	Comments
V1.0	31 July 2019	Geraldine Paterson	Final	

REVIEW

Name	Role	Date
L Eyquem	Innovation PMO Manager	19.07.19
P Turner	Innovation Manager	26.07.17

APPROVAL

Name	Role	Date
Steve Cox	Engineering & Technical Director	29.07.19

CONTENTS

GLOSSARY

Term	Description
AVC	Automatic voltage control
CLASS	Customer Load Active System Services
GB	Great Britain
MVA	MegaVoltAmpere
MW	MegaWatt
LDC	Load drop compensation

1 EXECUTIVE SUMMARY

1.1 Aims

The aims of this project were to define the technical requirements for an alternative to reinforcement to facilitate the connection of new generation whilst maintaining voltages within statutory limits for all customers.

1.2 Methodology

Modelling and simulation work was carried out to assess the effect of significant generation on voltage control. This work developed new settings which were implemented at a trial site to understand the real world impacts.

1.3 Outcomes and Key Learning

The project successfully developed settings which allowed effective voltage control at a substation with significant generation connected. Guidance on the calculation of these settings have been produced and is available to other DNOs.

Further modelling work was carried out to understand if alternative connection methods could be used to address the issue. Requirements for these alternative methods have been produced and are available to other DNOs.

1.4 Conclusions

The Enhanced Automatic Voltage Control project successfully demonstrated a method of maintaining voltages, within statutory limits, for networks with significant generation connected.

2 PROJECT FUNDAMENTALS

Title	Enhanced Voltage Control
Project reference	NIA_ENWL011
Funding licensee(s)	Electricity North West Limited
Project start date	November 2015
Project duration	3 years
Nominated project contact(s)	Geraldine Paterson (innovation@enwl.co.uk)

3 PROJECT BACKGROUND

The LCNF Second Tier project CLASS has now reached a conclusion and has proved there is a relationship between voltage and demand which can be exploited to reduce peak demand and assist with balancing generation.

Although CLASS provided a fit for purpose technical solution it is recognised that other solutions more appropriate for business as usual rollout and the services required could be available.

Part A of this project will further develop the technical solutions to meet the required CLASS functionality. These technical solutions could include local and / or centralised solutions.

Separately the government targets for reduction in CO_2 emissions and the use of renewable energy has led to a significant increase in large scale generation connected to the 11kV and 33kV distribution networks. This increase in generation has resulted in difficulties controlling the voltages supplied to customers. Voltage control is normally carried out using on-load tapchangers fitted to 33/11kV transformers and fixed tapchangers on distribution transformers. This arrangement has proved sufficient for the passive networks operated by DNOs for many years. The connection of generation can lead to extreme conditions such as maximum demand / minimum generation which results in low volts and minimum demand / maximum generation which results in high volts. To add to the complexity each of these conditions could occur simultaneously on different feeders from the same transformer.

Part B of this project will devise and apply new settings which can cater for this increase in generation.

Part C of this project will investigate the technical feasibility of a solution to offer new generators a "voltage managed" connection which will help to solve the voltage issues described above.

A more detailed breakdown can be found below.

Part A – Alternate Technical Solution for BaU Deployment of CLASS

This part of the project will investigate the different possible solutions to deliver the functional requirements requested by a developed commercial framework. The preferred solution will be trialled at two sites on the Electricity North West network to perfect the installation requirements. The output will be a suite of documents to allow the purchase, installation and commissioning of the technical solution.

Part B – Advanced AVC Settings for Generation

This part of the project will review and amend Electricity North West's voltage control policy to devise new settings for generator connections. These new settings will investigate the practicalities of both local and centralised application and the use of functions such as Load Drop Compensation. These new settings will also need to be aligned with the CLASS functionalities as defined in Part A. The new settings will be trialled at a number of primary substations on the Electricity North West network. To confirm the correct operation of the new settings measurements will be taken on the network close to customers to ensure there is no adverse impact on the voltage.

Part C – Technical Solution for Voltage Managed Connections

This part of the project will investigate the technologies required to enable a Network Operator to offer a new generator a voltage managed connection. The output of this part will be a functional specification for the technical solution.

4 PROJECT SCOPE

This project will define the technical requirements to allow a GB rollout of the CLASS learning. The project will also provide new AVC settings for generator connections and investigate a technical solution to enable the offering of voltage managed connections for generators.

5 OBJECTIVES

The project has the following objectives:

- Devise appropriate technical solutions to meet the functional requirements for CLASS
- Trial technical solutions as necessary on the Electricity North West network
- Produce relevant documentation to allow future installations
- Devise new settings for generator connections
- Application of new settings at a number of primary substations on the Electricity North West network
- Develop a functional specification for a technical solution to enable the offering of voltage managed connections.

6 SUCCESS CRITERIA

- Successful trial of the business as usual technical solution for CLASS
- All relevant documents produced to allow purchase, installation and commissioning of the technical solution
- Settings devised for generator connections
- Successful trial of new settings for generator connections on a number of primary substations
- New voltage control policy incorporating the new settings
- New functional specification for a technical solution to enable the offering of voltage managed connections.

7 PERFORMANCE COMPARED TO THE ORIGINAL PROJECT AIMS, OBJECTIVES AND SUCCESS CRITERIA

7.1 CLASS

Following the registration of this project Electricity North West was encouraged by Ofgem and National Grid to progress the CLASS component of the enhanced voltage control project to wide scale deployment as soon as possible. Rather than waiting on the results of this project a tender was initiated using the existing functionality developed as part of the Second Tier project, CLASS. Therefore the CLASS element was removed from this project.

7.2 Voltage Control for Generator Connections

To enable settings to be devised for generator connections an accurate model of the proposed trial site was built in the IPSA 2 power system analysis software.

The trial site was chosen as it had shown particular issues with achieving voltage control owing to the significant generation deployed downstream. The generation installed is 14MW of gas turbines and the transformers at the primary substation are rated at 10/14MVA. This generation runs all year round and either matches or exceeds the site demand for real power. Historically voltage control schemes have struggled with this because the net power flow measured at the transformer is at or about 0MW and the power factor constantly fluctuates due to reactive power flow.

A number of simulations were carried out to replicate different network conditions and focussed on the following:

- Model calibration
- Specific scenarios for simulations, both real and extreme
- Voltage drop across primary transformers in different scenarios
- Voltage drop across feeders in different scenarios
- Voltage drop at remote points of the network in different scenarios

The simulation scenarios changed the load level, generation level and generation power factor and the results showed that the generation has a major effect on the voltage drop across both transformers and a minor effect on the voltage drop at nodes remote to the substation busbars.

The results gave a maximum voltage drop across the network of around 6% and a voltage drop at full load at nodes closest to the substation busbars of around 1%. The maximum voltage rise at the substation busbars is around 5% at full generation.

This work led to the following settings for the AVC scheme:

- Basic voltage target to remain the same
- Bandwidth to remain the same
- LDC = 3.5%.
- Generator bias = 3%.
- Feeders with generators connected to be measured by the new enhanced AVC relay with their functions set to 'Generator'.
- No reverse LDC is required.

The study gave an indication of the maximum and minimum voltage drop across feeders and the maximum voltage rise caused by generation and allowed the calculation of appropriate settings. The full details of the simulation work are in Appendix A.

We installed the Fundamentals SuperTAPP SG enhanced AVC relay with the new settings calculated during the simulation work. These new settings were monitored for a 12 month period using measurements taken at the substation and at remote points to ensure all voltages remained within statutory limits.

To mitigate the voltage rise current transformers were installed to measure the generation connected to the busbars. The measurements, along with an estimation of generation connected further down the feeders, were used by the relay in conjunction with the generator bias (Gen Bias) function to reduce the busbar voltage and maximise the voltage headroom.

To maintain the voltage at all remote points Load Drop Compensation (LDC) was used to offset the voltage drop across feeders. The LDC functionality increased the voltage of the busbar in proportion to the measured, calculated and estimated substation load.

The outputs of the simulation and trials allowed the production of a settings guide and a functional specification for voltage managed connections.

8 THE OUTCOME OF THE PROJECT

8.1 Voltage Control Trials

The modelling and simulation work resulted in new settings which were applied at the trial site and monitored for 12 months. The full trial analysis can be found in Appendices B and C.

The applied settings:

- achieved smooth paralleling of the transformers,
- overcame the 'voltage rise at the point of common coupling' issue introduced by distributed generation,
- offset the voltage drop across the feeders, and
- paralleled adjacent substations successfully

Historically voltage control schemes have struggled at this site because the net power flow measured at the transformer is at or about 0MW and the power factor constantly fluctuates due to reactive power flow; these issues have now been resolved with the enhanced AVC settings.

8.2 Voltage Control Settings Guide

Following the successful outcome of the trial Fundamentals produced an "Enhanced Automatic Voltage Control Settings Calculation Guide" (see Appendix D). The guide provides the knowledge required to design and calculate the settings to accommodate for basic and advanced voltage control applications. It also gives a background of voltage control techniques, paralleling methodologies and additional network services.

The guide provides information on the following basic voltage control settings:

- Voltage target
- Network parameters
- Transformer parameters
- VTs and CTs
- Voltage target adjustments
- Tapchanger parameters
- Alarms
- Binary Inputs and Outputs
- Settings Groups
- Busbar grouping using settings groups

The guide provides information on the following advanced voltage control settings required for applications such as generator connections, system interconnectors and excluded loads:

- Fast tap
- Generator Bias
- Reverse LDC
- Reverse power factor.
- Network circulating factor and substation paralleling.
- Source impedance.
- Bus section connection
- Reverse current limit
- Load Ratio
- CT function
- Tapchanger scheme
- Busbar grouping using CB statuses.

Electricity North West is incorporating this settings guide into their internal policies for use in setting of future voltage control schemes.

8.3 Voltage Managed Connections

The Enhanced AVC technology focused on the traditional voltage control at primary substations and grid substations using On-Load Tapchangers (OLTC) to adjust the network voltage level dynamically in relation to the generator export/import status but there may be other solutions.

Some of the main challenges introduced by generation are voltage rise at the Point of Common Coupling (PCC), Reverse Power Flow (RPF) and load masking. Additionally, as generation exists naturally in a scattered way within the distribution network, coordinating them to achieve a common objective can be challenging. Moreover, some generation depend on energy sources affected by weather conditions and other variables; such as wind and solar farms. This introduces another layer of complexity to the system as it makes forecasting and planning even more difficult.

OLTC based voltage control systems can be enhanced to cope with these negative effects. However, OLTC voltage control is a centralised type of voltage control with a wide effect on a significant portion of the network. This centralised effect makes it hard to optimise the voltage level at or around PCC points without affecting the whole system served by the same HV substation.

Appendix E details alternative decentralised voltage control approaches where generators could provide the voltage control needed for the system. Electricity North West is using the functional requirements for voltage managed connections detailed in Appendix E for to develop a flexible connection offering.

9 REQUIRED MODIFICATIONS TO THE PLANNED APPROACH DURING THE COURSE OF THE PROJECT

Following the registration of this project Electricity North West was encouraged by Ofgem and National Grid to progress the CLASS component of the enhanced voltage control to wide scale deployment as soon as possible. Rather than waiting on the results of this project a tender was initiated using existing functionality developed as part of the Second Tier project CLASS. Therefore the CLASS element was removed from this project resulting in one trial installation rather than the 6 envisaged at the start of the project.

10 PROJECT COSTS

Item	Category	Estimated Costs £k	Final Costs £k rounded	Variance
1	Project Management	100	81	-19%
2	Installation & Materials	600	79	-86%
4	Trial Analysis	100	31	-69%
	Total	**800**	**191**	-76%

All variances are as a result of the removal of the CLASS element from the project.

11 LESSONS LEARNT FOR FUTURE PROJECTS

This project has shown that modelling and simulation stages can take more time than anticipated. The more accurate the model, the more time is required to construct the model.

Online monitoring functionality has proved beneficial in determining the accuracy of the model and developing the settings. Monitoring equipment was installed on the LV network at a remote point to collect voltage measurements and at the trial substation to monitor the performance of the SuperTAPP SG relays.

The substation monitoring equipment provides 24/7 online monitoring facilities which allowed oversight of the operation of the new equipment at all times. Having the online monitoring also allowed a fast response to any issues caused by the new settings.

12 PLANNED IMPLEMENTATION

Electricity North West has already installed the Fundamentals SuperTapp SG relay at approximately 200 sites for the CLASS rollout. This gives access to the enhanced settings produced from this project. We will use these enhanced settings at any site with significant generation which causes issues controlling the voltage.

When the specification and contracts have been fully developed for voltage managed connections we will offer this as an alternative to reinforcement for new generator connection applications.

13 DATA ACCESS

Electricity North West's innovation data sharing policy can be found on our website.

All measurement data can be made available on request.

14 FOREGROUND IPR

There is no foreground IPR associated with this project.

15 FACILITATE REPLICATION

The guide for calculating the settings produced as part of this project is available on the Electricity North West website as Appendix D to this report.

The relay deployed was the SuperTapp SG AVC relay is available from Fundamentals. Fundamentals, our project partner, will also provide any guidance and assistance needed for installation or setting of the relay.

Guidance on the requirements for voltage managed connections is contained in on the Electricity North West website as Appendix E to this report.

Any Electricity North West policies produced following this project can be made available ot other DNOs on request.

16 APPENDIX

Appendix A	Modelling, Simulation Methods and Simulation Results
Appendix B	Evaluation of the New EAVC Settings: Part 1
Appendix C	Evaluation of the New EAVC Settings: Part 2
Appendix D	EAVC Settings Calculation Guide
Appendix E	Distributed Generation Controllers and Voltage Managed Connections