electricity north west
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SMART STREET

Optimisation Implementation Strategy

28 February 2018

VERSION HISTORY

Version	Date	Author	Status	Comments
First draft	20 February 2018	B Ingham	0.1	
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CONTENTS

LIST OF ACRONYMS

Acronym	Explanation
BAU	Business as usual
BS	British Standard
CRMS	Control room management system
CVR	Conservation voltage reduction
DG	Distributed generation
DNP3	Distribution Network Protocol 3
DSSE	Distribution System State Estimator
HV	High voltage (11kV / 6.6kV)
ICCP	Inter-control centre communications protocol
LCT	Low carbon technology
LCNF	Low Carbon Networks Fund
LV	Low voltage (400V / 230V)
NMS	Network management system
OLTC	On load tap changer
RTU	Remote terminal unit
SP5	Spectrum Power 5 (Siemens optimisation software)
VVC	Volt/Var control

1 INTRODUCTION

1.1 Purpose of document

The purpose of this document is to achieve the associated deliverable related to the following Smart Street **SDRC 9.4.6 – Publish an Optimisation Implementation Strategy on the Smart Street website by February 2018.**

This document describes the means by which a communications network, required to run Smart Street, can be established and also the settings used during the trial phase.

1.2 What is Smart Street

Smart Street aimed to utilise advanced real time optimisation software to simultaneously manage high voltage (HV) and low voltage (LV) network assets to respond to customers' changing demands. Voltage management on HV networks aimed to reduce network losses while conservation voltage reduction (CVR) on the LV networks aimed to reduce energy demand. Capacitor banks on the HV network were utilised to help manage network losses by adjusting the network's power factor. On the LV network, a mix of capacitor banks and controlled meshing of networks were integrated to flatten the voltage profile and improve energy efficiency. The meshing of LV networks also aimed to release additional network capacity.

1.3 Conservation voltage reduction (CVR)

Electrical equipment made for the European market, including household appliances and lighting, is designed to operate most efficiently in the region of 230 to 220 volts. This equipment can, however, operate adequately at voltages in the region of 200 volts. If power is delivered at voltages higher than these optimum levels, energy is consequently wasted. Excess voltage can shorten the useful life of electrical equipment, since the excess energy is dissipated as heat. Therefore, optimising network voltages reduces overall energy consumption, improves power quality and extends the life of customers' equipment. Smart Street proposed to optimise network voltages by using CVR on the LV trial networks.

CVR on a distribution network is defined as a reduction of energy consumption resulting from a decrease in feeder voltage. Smart Street proposed to optimise the voltage by utilising on-load tap changing (OLTC) transformers. These transformers were able to regulate the voltage along the feeder while maintaining statutory limits. This allowed for the peak load to be reduced, hence reducing annual energy consumption.

Additionally Smart Street utilised shunt capacitors on the LV feeders to allow for a voltage boost at the end of the circuit to reduce voltage drop. This allowed for a flatter voltage profile, allowing for the OLTC to tap closer to the lower limit.

1.4 LV network meshing

In addition to the proposed CVR techniques, Smart Street assessed the benefits of meshing LV networks to balance load while releasing network capacity at times of high demand.

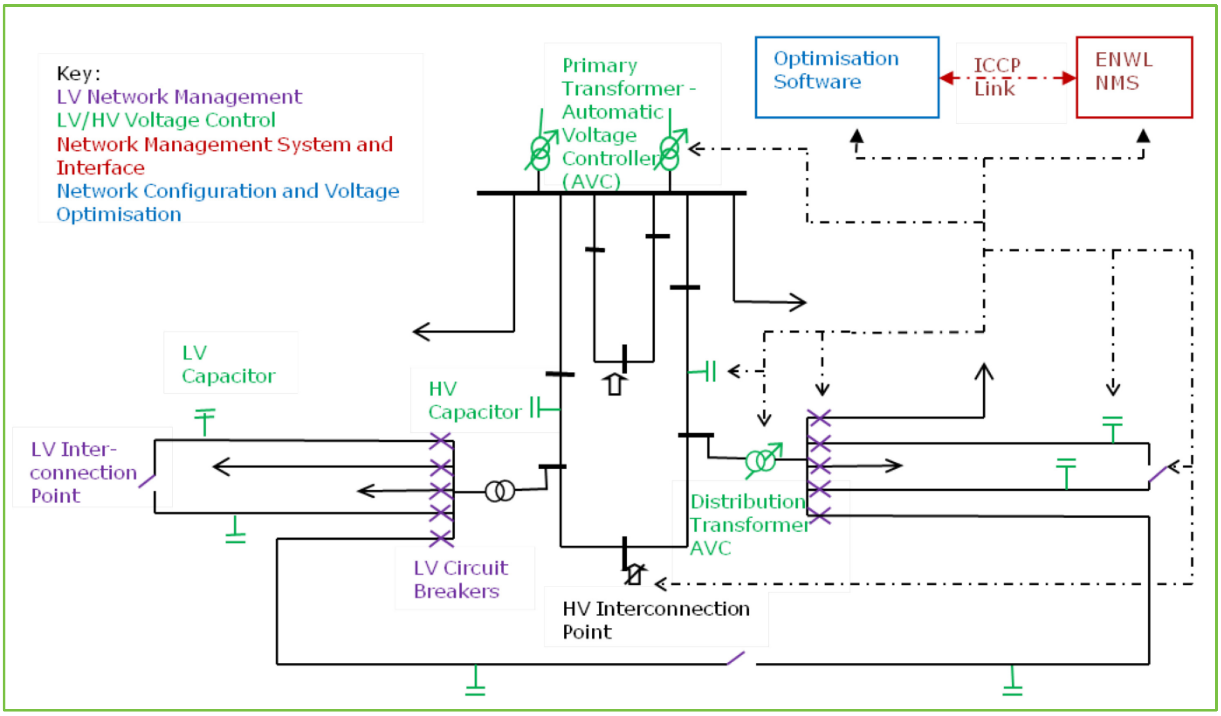
Our project partner, Kelvatek, developed new controllable retrofit vacuum switching devices especially for this project. These devices were utilised at the existing distribution boards and in link boxes across the LV trial circuits. The devices have the capability to be remotely controlled allowing sensing of feeder flows and reconfiguration of the LV network.

1.5 Control systems

Figure 1 shows an example of how the various Smart Street technologies were installed across the trial networks. The optimisation included the ability to optimise for violations, losses and to minimise load as a single VVC function. The opportunity to mesh the trial networks was also included in this function, but radial configurations were the preferred running arrangement. This was specified to minimise customer outages during electrical faults. Therefore the switching equipment was closed (creating loop or meshed networks) if the objective-function resulted in positive changes to the network above a set threshold.

The optimisation application calculated the optimal procedures to reach the optimisation objectives, which could be different for HV and LV depending on the chosen function. The user could choose if the switching equipment was included or inhibited in the optimisation scheme and only specified remote controlled switches were included in the optimisation.

Figure 1: Smart Street network management



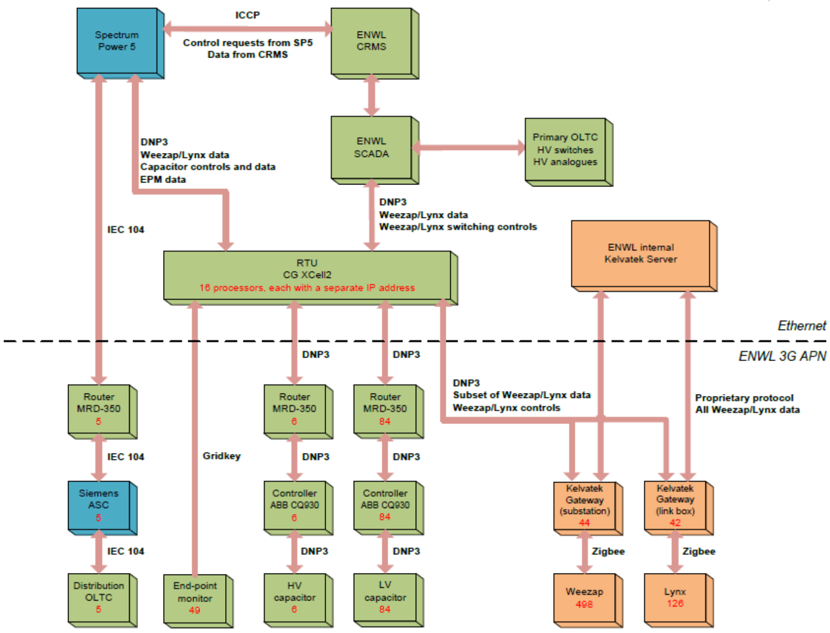
2 SMART STREET TRIAL SET-UP

During the trials the data architecture was set up as shown in Figure 2 below. The various switching devices were categorised as switching (Weezaps and Lynx) or voltage control (capacitors and on load tap changers (OLTCs)). This segregation was used to determine the routes by which the controls from the optimisation software were sent out.

For the switching devices the controls were passed across the inter-control centre communications protocol (ICCP) link to Electricity North West's control room management system (CRMS) and from there out to the field devices via Electricity North West's existing supervisory control and data acquisition (SCADA).

For the voltage control devices the controls were sent directly from the Spectrum Power 5 (SP5) system, apart from the primary OLTCs as they already reported directly into CRMS as part of business as usual. Due to the variety of data routes involved in this set-up, a number of remote terminal units (RTUs) were installed to act as data concentrators and splitters.

Figure 2: Smart Street trial architecture



Equipment counts in red. Please treat these as an indication, as they are subject to change throughout the lifetime of the project.

2.1 Kelvatek devices

The Weezap and Lynx devices were connected to a local gateway, which acted as an RTU, via the ZigBee protocol. The gateway then connected to the CG RTU located in the server room at the Electricity North West control centre, via DNP3 over the 3G network. These devices were also connected to a separate virtual server, also located in the Electricity North West control centre, using a proprietary protocol. This server was used to provide the fault location services. The Weezaps could mimic the standard British Standard (BS) fuse curves for a variety of sizes, up to 400A, and were also configured to provide up to five automatic recloses onto a fault to reduce the impact of transient faults on customers.

2.2 Capacitors

Both the high voltage (HV) and low voltage (LV) capacitors used the same set-up with a local control unit connected to the unit with a category 5 ethernet cable. An additional router was connected to the control unit which allowed the equipment to communicate over the 3G network back to the central systems. All communications for these units were via DNP3. The HV capacitors were all single stage devices, two 200kVAr and one 400kVAr for the three ground-mounted and 500kVAr for the overhead units. The LV capacitors were multi-stage devices with steps of 50kVAr and 100kVAr; depending on the network they had total sizes of 100, 150 or 200kVAr. All the capacitors had local under- and over-voltage settings that would automatically operate the unit should any excursion be detected.

2.3 On load tap changers (OLTC)

The OLTCs were connected over the 3G network via a local controller directly into the SP5 system, bypassing the RTUs, and communicating using the IEC104 protocol. The voltage level was controlled by a set-point sent from the system as determined by the optimisation software. To safeguard against the loss of comms the local controller had a default set-point of 245V programmed that was used in the event that no signal was received for more than a predefined period. For the transition into BAU use it is envisioned that this functionality would not be required.

2.4 End point monitors

Monitoring devices were installed on the radial LV circuits to give visibility of voltages at the end of the cable run. These connected via the 3G network using a proprietary protocol which was converted into DNP3 by the RTUs.

2.5 Spectrum Power 5

The optimisation of the network was driven by the SP5 software, which assessed the system every thirty minutes and then sent controls out to reconfigure the network accordingly. The system received data from all the Smart Street equipment on a one minute average basis; it also received the telemetered data for the business as usual (BAU) equipment via the ICCP link.

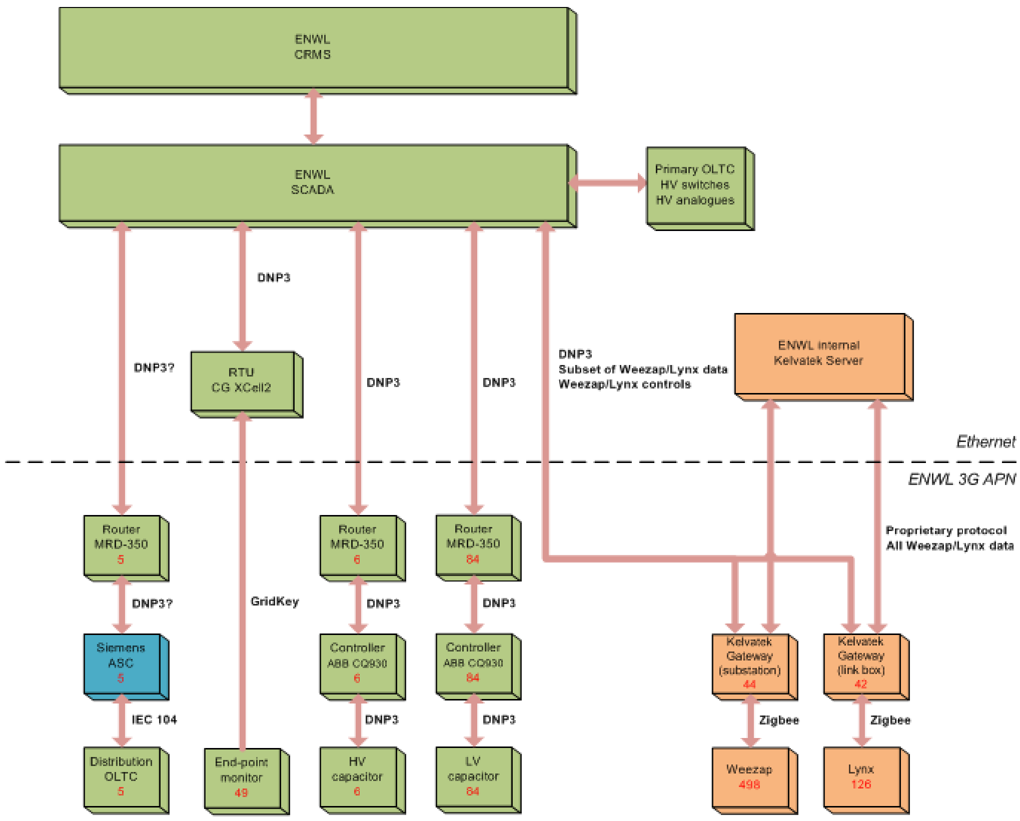
This data was fed into the Distribution System State Estimator (DSSE) which determined the current state of the network. The Volt/Var control (VVC) algorithm then used this to calculate the optimum running arrangement for the network given both the observed and calculated power flows. The software was tasked with looking to reduce the LV energy absorbed and the HV losses, as well as ensuring that all equipment was run within its ratings.

3 ISSUES

3.1 System design

As can be seen from Figure 2 above, the design used during the trials was overly-complicated, in part due to the requirement to use an off-the-shelf system for the top end rather than Electricity North West's existing network management system (NMS). This, coupled with the multiple communications routes led to the requirement for the RTUs to be installed to manage the data flows to the two systems. For a BAU approach this complication could be reduced by removing the additional system and having the devices connected directly to the top end system, thus reducing the number of RTUs required; Figure 3 shows this new configuration.

Figure 3: Proposed data architecture



Equipment counts in red. Please treat these as an indication, as they are subject to change throughout the lifetime of the project.

4 PARAMETERS

4.1 Optimisation software

The sections below discuss the parameters used during the trial phase of the project and any adjustments that may be necessary once we transition to BAU. Please note that these are based on the experience gained during the trials and as such may need further review as the Smart Street methodology is expanded to encompass the remainder of the Electricity North West network.

4.1.1 Frequency of operation

The frequency at which the software looks to optimise the network is a trade-off between performance, number of operations and the speed of response to changing conditions. Work carried out under the First Tier LCN Fund project, LoVIA (Low Voltage Integrated Automation) concluded that a thirty-minute optimisation period was sufficient to allow the system to respond to changes in demand and generation without leading to performance issues due to the software re-calculating the system state for negligible changes. In scaling up the system to cover the full network there are no issues envisaged.

4.1.2 Meshing

The system was set to mesh where the resultant improvement in the objective function produced a predicted improvement of ≥5% and to un-mesh where the current flowing through the device was ≤20A and the predicted decrease in the objective function was ≤5%. This gave the system the ability to manage power flows where necessary without exposing customers to the additional risk of faults at times where meshing was of limited benefit.

4.2 Objective function

The Smart Street system was set to optimise the network such that it aimed to reduce the LV energy consumption and the HV losses. While there is an inherent conflict in these objectives, this allowed the system the flexibility to react to the variations in the load profile; ie at periods of high demand it was more beneficial to reduce consumption while at low demand periods the converse was true.