Low Voltage Integrated Automation (LoVIA)

A fully integrated control system for the low voltage network using remote voltage measurement

Bringing energy to your door

Introduction

The LoVIA 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 tap changers installed and was encoded into a remote terminal unit which provided the interface to the tap changer and the central control room. The remote voltages required for the algorithm were measured by a monitoring unit connected to the low voltage (LV) cables via a smart joint which was developed as part of our Low Voltage Network Solutions project.

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 this form of voltage control could offer advantages as the demand and generation mix changes in the future.

The project has shown that the functionality of existing technologies such as an LV monitoring system and an on-load tap changer 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 tap changer 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 tap changer operation.

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

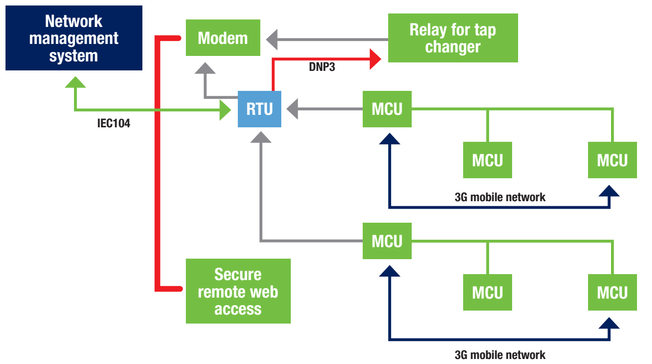
Background

The adoption of low carbon technology at scale can be shown to introduce significant challenges for distribution network operators (DNOs) in relation to the control of network voltages; a number of innovative methods for managing these voltages are being explored. However, network analyses show that the presence of low carbon technology at scale will result in varied voltage profiles. 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. These devices will need to form an integrated voltage control platform where their action is appropriately coordinated. Low Voltage Integrated Automation (LoVIA) demonstrated the applicability of this control platform.

LoVIA architecture

LoVIA integrated four separate components: an automatic voltage control algorithm developed by the University of Manchester; LV monitoring units (MCUs); a tap change control relay and the network management system. All of these components were integrated using a remote terminal unit (RTU). A schematic of the project's architecture is shown below.

LoVIA architecture



Control logic

The voltage control logic changes the busbar target voltage based on the voltages at the busbar as well as mid and end points. The target voltage is determined for every control cycle.

Taking the busbar voltage as a reference, a compensating voltage (DVi) is calculated for each control cycle. Using the measured maximum and minimum voltages the table below shows a compensating factor which should be multiplied by the voltage of one tap step to give the compensating voltage.

Compensating voltage factor according to the voltage zones

		Maximum				
		>253V	253-248V	248-221V	22-216V	<216V
Minimum	>253V	+3				
	253-248V	+2	+2			
	248-221V	+2	+1	0		
	221-216V	+1	0	-1	-2	
	<216V	0	-1	-2	-2	-3

The new set-point voltage (Vset i+1) is then obtained by calculating the difference between the measured busbar voltage (Vbusbar i) and the compensating voltage (DVi).

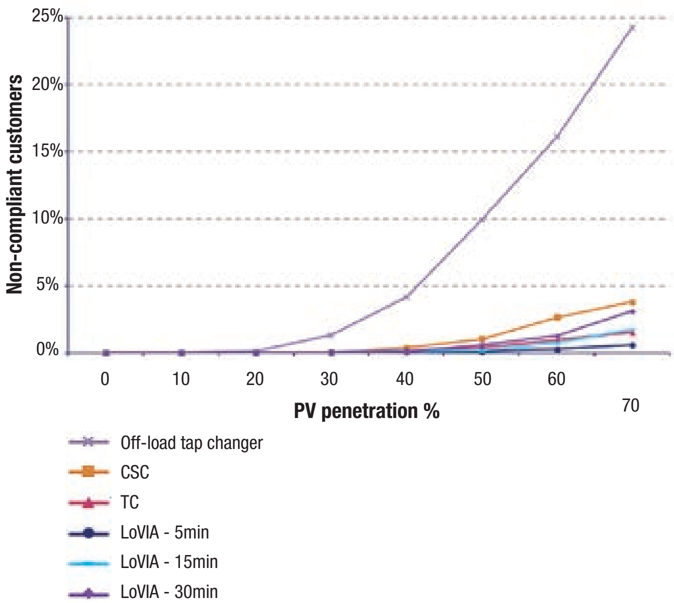
Project results

The performance of the LoVIA control algorithm is examined by comparing it with alternative control strategies that could be used in LV networks. These voltage control strategies are:

- Off-load tap changer – the off-load tap changer is set to tap position 4, ie, +2.5% to cope with PV systems
- Constant set-point control (CSC) – the voltage set-point is kept at a fixed value of 1.04pu throughout the year
- Time-based control (TC) – The voltage set-point is changed according to the time of the day. During minimum demand a set-point voltage of 1.03pu is used whereas during peak this value is set to 1.05pu.

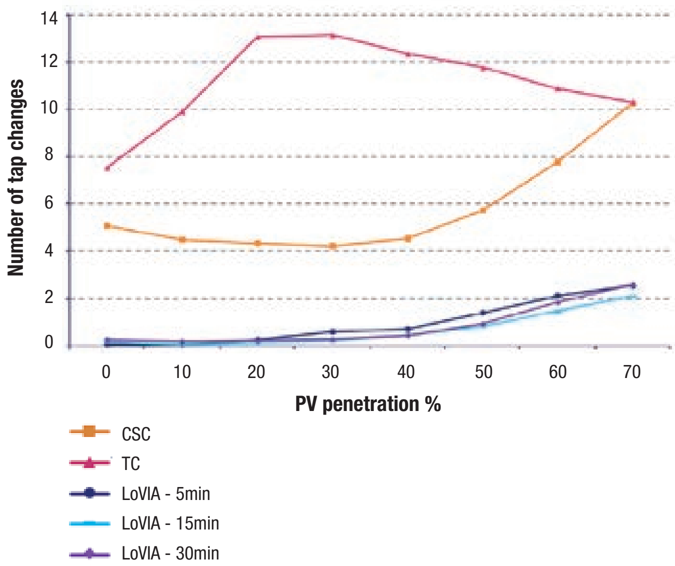
The graph below shows that when the off-load tap changer is deployed, customers experience voltage issues from 30% of PV penetration; with a 70% penetration, one in four customers could experience voltage issues. However, when the on-load tap changer is installed, irrespective of the control strategy, it is only after 50% of PV penetration that customers might experience voltage problems.

Customers with voltage problems – comparison (annual average)



Although the time-based control (TC) strategy results in a better mitigation of voltage issues than constant set-point (CSC) and is comparable with the LoVIA control, this is mostly done at the expense of more tap operations. Overall, the LoVIA 30-minute control strategy results in a much better mitigation of voltage issues than TC and CSC, and with only a fifth of the tap operations, as shown below.

Daily average number of tap changes – comparison (annual average)



The analysis shows that LoVIA is the best control strategy out of the three assessed. 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 operation, eg, targeting voltage compliance or fewer tap operations.

Low Voltage Integrated Automation (LoVIA) was a two and a half year project completed in April 2015.

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