Title: Deliverable 1.3 “Monitoring Aspects and Benefits” and Deliverable 2.1 “EVs and PV: Literature review and initial modelling”

Synopsis: This report presents a quantitative assessment of the benefits from adopting different levels of monitoring considering location, sampling and data latency. This report is also presents a summary of the literature review and current pilot projects investigating the control of EV and PV systems.

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Executive Summary

This report corresponds to Deliverable 1.3 “Monitoring Aspects and Benefits” part of Work Package 1 “On-load tap changing LV transformers” and Deliverable 2.1 “EVs and PV: Literature review and initial modelling” part of Work Package 2 “Control of Low Carbon Technologies” of the iCASE project “Active Management of LV Networks” jointly funded by EDF R&D and EPSRC.

The Active Management of LV Networks project has been established in order to investigate the effect of applying active management techniques to increase the ability of low voltage networks to accommodate higher number of low carbon technologies (LCTs), in particular photovoltaic (PV) systems and electric vehicles (EVs). The project will focus on the utilization of on-load tap changing transformers and coordinated control of LCTs themselves and other technologies to control voltages and congestion in the network.

Deliverable 1.2 presented a quantitative assessment of the benefits of adopting LV on-load tap changer (OLTC) fitted transformers considering different penetrations of low carbon technologies and penetrations per feeder. In this report, Deliverable 1.3 will provide a more detailed assessment of the benefits and disadvantages from adopting different levels of monitoring considering location (e.g., middle and end point of feeders) and control cycles (e.g., 1, 10, 20 and 30 minutes). In addition, a deterministic scenario considering uneven penetration of LCTs per feeder is investigated to assess the OLTC performance in such a scenario. The impact of different monitoring data latencies (e.g., 1, 10 minutes) on the proposed OLTC controller is also investigated and discussed in this document.

Furthermore, in order to reduce the need to install monitoring devices in all LV feeders a practical and scalable voltage estimation method, using limited network data, is also proposed in this report.

A summary of the main aspects of this report is presented below.

- **Voltage Control: Stochastic Approach.** A Monte Carlo Analysis is carried out on four French LV networks (specified in Deliverable 1.2) in order to capture the stochastic nature of load and LCTs so the ability of the OLTC control logic to deal with voltage issues can be assessed thoroughly. The process consists of running hundreds of times the algorithm presented in Deliverable 1.2, section 8.1. The analysis is performed considering different penetration levels of LCTs (i.e., PV systems and EVs), 2 different days (i.e., 28th November 2013 and 15th June 2014), monitoring at the middle and end points of each feeder, and different control cycles (i.e., 1, 10, 20, 30 minutes). The results of the Monte Carlo Analysis demonstrate the effectiveness of the proposed OLTC control logic in terms of EN50160 compliance and number of tap changes.

- **Influence of monitoring points and control cycles.** In terms of monitoring, the analysis demonstrates that for the four studied networks voltage sensors located either at the middle or end points of each feeder result in similar performances (EN50160 compliance). This is believed to be mainly due to the relative short distances of the feeders. In terms of the control cycles, it was found that by adopting 20 or 30 minutes it is possible to significantly limit tap operations (i.e., less impact on the OLTC utilization) while still minimizing the number of customers that could be affected by voltage issues.

- **Voltage Control: Uneven Penetration Scenario.** A deterministic scenario of uneven mixed penetrations of LCTs per feeder was implemented on one of the French networks (LV_02779) to assess the OLTC control logic on a challenging scenario (i.e., some feeders with much higher or lower voltages than others). The results demonstrate that the proposed OLTC control logic can still achieve a satisfactory performance (in terms of number of non-compliant customers and tap changes). This is due to the fact that voltage issues due to each technology (i.e., PV systems and EVs) appear at different times of the day.

- **Monitoring Data Latency.** The effect of incorporating two different latencies (i.e., 1 and 10 minutes) in the monitoring data transfer process and how this affects the performance of the OLTC control logic was investigated in this report. The analysis was performed on the
LV_02779 network considering 40% of PV penetration level during summer and applying OLTC control with end point monitoring and four control cycles (i.e., 1, 10, 20 and 30 minutes). The results showed that the latency does have a significant effect on the performance of the OLTC controller. Indeed, latency increased the number of non-compliant customers and the number of tap changes particular for short control cycle lengths (i.e., 1 and 10 minutes), especially in the case of 1-min control cycle and 10-min latency. The effect of latency however is significantly reduced with longer control cycle lengths (i.e., 20 and 30 minutes).

- **Remote Voltage Estimation.** A remote voltage estimation method is proposed in order to substitute the need for remote monitoring of end points. This method calculates the voltage drop (or rise) at the end of the feeder by considering information that is monitored at the substation only (phase voltage, active and reactive power per phase) as well as assumptions regarding the typical nature of French residential LV feeders (i.e., average impedances). The control logic was applied considering the estimated voltages and applied to the LV_02779 network for two deterministic cases with specific LCT penetrations. Results demonstrate that the use of the proposed technique to estimate voltages can be as effective (in terms of non-compliant customers) as that when using monitoring. However, further analyses are required to more thoroughly assess its performance.

- **EV and PV Control.** In Deliverable 2.1 a literature review was carried out on the active management of LCTs (EVs and PV systems) so far proposed by researchers and industry, particularly those who have been involved in actual trials. Possible control interactions with EVs and PV systems were identified and initial control models (e.g., centralised, decentralised) were discussed.
# Table of Contents

## Executive Summary

Table of Contents

1. **Introduction**
   - Voltage Control Logic .............................................................. 6
   - French LV Networks ....................................................................... 6

2. **Effects of Monitoring Points and Control Cycles**
   - Simulation Results: PV Case .......................................................... 7
   - Number of EN50160 non-compliant customers ................................ 7
   - Number of Tap Changes .................................................................. 9
   - Probability of Technical Problems ............................................... 10
   - Transformer and Feeders First Segment Utilization Level ................ 11

3. **Effects of Uneven LCT Penetrations per Feeder**
   - Case Study Definition .................................................................... 18
   - Simulation Results ........................................................................... 19
   - Summary .......................................................................................... 21

4. **Effects of Latency**
   - Modelling Latency ........................................................................... 22
   - Simulation Results ........................................................................... 23
   - Summary .......................................................................................... 27

5. **Voltage Control using Remote Voltage Estimation**
   - Remote Voltage Estimation ............................................................ 28
   - Estimation of the Number of Customers Connected per Phase ........ 28
   - Generic Feeder Model ..................................................................... 30
   - Voltage Estimation ......................................................................... 31
   - Simulation Results: PV Case ............................................................ 31
   - Simulation Results: EV Case ............................................................ 32
   - Discussion ......................................................................................... 34
   - Summary .......................................................................................... 34

6. **Control of EVs and PV Systems**
   - EV Control ....................................................................................... 36
   - Literature Review ............................................................................. 36
   - Pilot Projects ..................................................................................... 37
   - PV Control ........................................................................................ 38
   - Literature Review ............................................................................. 38
   - Pilot Projects ..................................................................................... 39
   - EV and PV Control Modelling Aspects ............................................ 39

7. **Conclusions**

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