Title: Deliverable 2.3 “Benefits of controlling EVs and PV in combination with other technologies”

Synopsis: This document presents a quantitative assessment of the benefits of adopting different control strategies (local, centralised or combination) with the additional control of other technologies (i.e., OLTC) that could help managing voltages and congestion. This assessment considers different control strategies, locations and penetrations of low carbon technologies, different control cycles and LV networks.

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Prepared For: Mr Luc Glorieux
EDF R&D, France
Distribution Network Automation and Protection
1, avenue du Général de Gaulle, 92140 Clamart

Mr Sébastien Vilbois
EDF R&D, France
Distribution Network Automation and Protection
1, avenue du Général de Gaulle, 92140 Clamart

Prepared By: Mr Andreas T. Procopiou
The University of Manchester
Sackville Street, Manchester M13 9PL, UK

Revised By: Dr Luis(Nando) Ochoa
The University of Manchester
Sackville Street, Manchester M13 9PL, UK

Contacts: Dr Luis(Nando) Ochoa
+44 (0)161 306 4819
luis.ochoa@manchester.ac.uk

Mr Andreas T. Procopiou
+44 (0)161 306 4504
andreas.procopiou@manchester.ac.uk
Executive Summary

This report corresponds to Deliverable 2.3 “Benefits of controlling EVs and PV in combination with other technologies” 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 utilisation of on-load tap changing transformers and coordinated control of LCTs themselves and other technologies to control voltages and congestion in the network.

Deliverable 2.2 provided the quantification of benefits from controlling PV systems and EVs adopting decentralised (i.e., local) and centralised control approaches. The performance of each proposed control approach was investigated using a Monte Carlo framework considering different penetration levels (0 to 100%) for each LCT. This report, Deliverable 2.3, provides a quantitative assessment of the benefits of adopting different control approaches (centralised, decentralised and combination) with the additional control of other technologies (in particular the OLTC) that could help managing voltages and congestion. The assessment of the different control approaches is investigated on seven French LV networks considering different locations and penetrations of low carbon technologies along with different control cycles.

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

Decentralised PV Control. A fully decentralised control scheme combining the decentralised Volt-Var and Volt-Watt control with 10% over-rated inverters is carried out considering different penetration levels of PV systems for different days in summer (i.e., lowest demand days) and applying a Monte Carlo analysis. Three control settings (combination of volt-var and volt-watt curves) were investigated where priority to act first was given to the Volt-Var control achieving that way to solve voltage issues without curtailing generation. No thermal management is carried out.

- **Voltage issues.** In general, all customers were compliant with EN50160 with this approach and the same performance is achieved with all investigated LV networks.
- **Asset utilisation.** Either control setting increases the maximum utilisation level of both transformer and feeders. This is due to the fact that the PV inverters absorb reactive power. In cases where voltage issues cannot be solved with volt-var control (reactive power absorption), volt-watt is acting to reduce voltage by reducing generation. In such cases maximum utilisation reduces.
- **Energy production.** Curtailment is limited in most studied cases.

Centralised PV Control. A fully centralised control scheme combining the decentralised Volt-Var and Volt-Watt control with 10% over-rated inverters is carried out considering different penetration levels of PV systems and three control cycles (i.e., 10, 20 and 30-min). The investigation is performed for different days in summer (i.e., lowest demand days) and applying a Monte Carlo analysis. The OLTC control is applied 1 min after the PV centralised thermal controller to ensure adequate coordination.

- **Voltage issues.** In general, all customers were compliant with EN50160 with this approach. The same performance was achieved with all control cycles.
- **Asset utilisation.** The maximum utilisation level of both transformer and feeders was significantly reduced to values close to the capacity limits; asset utilisation is always below 110%. The same performance was achieved with all control cycles.
• **Energy production.** As expected, energy is curtailed at high penetration levels (assets are overloaded if no control is applied) disregarding the control cycle. For instance, for LV_02779, curtailment starts from 2.8% at 60% penetration and goes up to 22% at 100% penetration.

**Centralised EV Control.** A fully centralised control scheme combining the OLTC control logic and the centralised EV charging point management is carried out considering different penetration levels of EV systems and three control cycles (i.e., 10, 20 and 30-min). The investigation is performed for different days in winter (i.e., highest demand days) and applying a Monte Carlo analysis. The OLTC control is applied 1 min after the EV charging point management to ensure adequate coordination.

• **Voltage issues.** All customers are compliant with EN50160 with any of the control cycles.

• **Asset utilisation.** The maximum utilisation level of both transformer and feeders was significantly reduced to values close to the capacity limits with any of the control cycles. Although results show that the maximum utilisation level of all assets is reduced, it was still found to be above their capacity limits. It was noticed that the shorter is the control cycle, lower is the percentage of time during a day which assets are overloaded. A lower thermal threshold could be a potential solution to this issue.

• **EV charging delays.** In general the charging delay increases for all penetration levels when the centralised EV control is applied with any of the control cycles. Almost the same performance was achieved with all control cycles. Slight differences were found only at very high penetration levels and for longer control cycles. For example, a 30-min control cycle leads to less charging delays compared with shorter control cycles (i.e., 10, 20 min) as the control is applied less often and therefore less EVs are managed.

**Mixed control.** A mixed control of the centralised and decentralised approaches is investigated to address thermal and voltage issues. The proposed control involves the coordinated control between the PV centralised thermal controller, the centralised EV charging point management and the decentralised voltage Volt-Watt control.

The performance of the proposed control approach is investigated for 0 to 100% of PV penetration levels considering different days in summer (i.e., lowest demand days) and control cycles (i.e., 10, 20, 30 minutes). The investigation is performed adopting the Monte Carlo analysis where each penetration level of PV is investigated for 0, 50 and 100% of EV penetration. Although no EV penetration level results in major technical issues during summer (i.e., the EV control is not used significantly), it helps reducing PV curtailment as the corresponding energy can be used to charge EVs.

• **Voltage management.** Without control, the simultaneous presence of EVs and PV systems helps to slightly reduce the number of EN50160 non-compliant customers. When control is applied all customers are compliant with EN50160 with any of the control cycles.

• **Asset utilisation.** The maximum utilisation level of both transformer and feeders was significantly reduced to values close to the capacity limits. Results show that asset utilisation is always below 100% (except for some cases in which goes up to 103%) for all control cycles. At low PV penetration levels the presence of EVs increases the maximum utilisation level as it mainly happens during the evening. At high PV penetrations, however, the presence of EVs reduces the maximum utilisation as it is predominant during daylight.

• **Energy production.** As expected, energy is curtailed at high PV penetration levels (assets are overloaded if no control is applied). However, the simultaneous presence of EVs with PV systems helps to reduce the level of curtailment. For example, considering the deterministic case of LV_02779 with 100% of PV penetration the curtailment with 0% of EV is 15.68% and is reduced to 12.06 and 9.12% with 50 and 100% of EVs. For the same network, the stochastic analysis showed that the curtailment of energy (compared to the case without EVs) can be reduced by an average of 2 and 4% at each PV penetration level with 50 and 100% of EV penetration level, respectively.
# Table of Contents

## Executive Summary

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## Table of Contents

1. **Introduction** .......................................................... 6

2. **LV Networks and Previous Control Strategies** .......................... 7

2.1 French LV Networks .................................................................. 7

2.2 Voltage management with LV OLTC-fitted transformer ............... 7

2.2.1 Control logic ........................................................................ 8

2.3 Centralised PV Thermal Control ............................................. 11

2.3.1 Control Logic ...................................................................... 11

2.4 Centralised EV charging point management .. ............................ 14

2.4.1 Control Logic ...................................................................... 14

3. **Decentralised PV Control** .................................................. 17

3.1 Control Logic ........................................................................... 17

3.2 Deterministic Example .......................................................... 18

3.3 Stochastic analysis .................................................................. 21

3.3.1 Voltage Issues ...................................................................... 21

3.3.2 Asset Utilisation ................................................................. 22

3.3.3 Energy Metrics .................................................................. 24

4. **Centralised PV Control** ...................................................... 26

4.1 Deterministic Example .......................................................... 26

4.2 Stochastic analysis ..................................................................... 28

4.2.1 Voltage Issues ....................................................................... 29

4.2.2 Asset Utilisation ................................................................. 29

4.2.3 Energy Metrics ...................................................................... 31

4.2.4 Control Actions ................................................................. 32

5. **Centralised EV Control** ...................................................... 34

5.1 Deterministic Example .......................................................... 34

5.2 Stochastic analysis ..................................................................... 37

5.2.1 Voltage Issues ....................................................................... 37

5.2.2 Asset Utilisation ................................................................. 38

5.2.3 Control Actions ................................................................. 41

5.2.4 EV User Metrics ............................................................... 42

6. **Mixed Control (Combined PV and EV Control)** ....................... 47

6.1 Volt-Watt settings ..................................................................... 47

6.2 Deterministic Example .......................................................... 47

6.3 Stochastic analysis ..................................................................... 50

6.3.1 Voltage Issues ....................................................................... 50

6.3.2 Asset Utilisation ................................................................. 51

6.3.3 Energy Metrics ...................................................................... 55

6.3.4 Control Actions ................................................................. 56

6.3.5 EV user metrics ................................................................. 57

7. **Conclusions** ........................................................................ 61

8. **Next Steps** ........................................................................... 64

9. **References** ........................................................................... 65

10. **Appendix** ........................................................................... 66
Influence of adopting EV charging point management with OLTC

LV_01734
LV_01523
LV_01521
LV_01519
LV_01527
LV_00016

Centralised EV Control

LV_01734
LV_01523
LV_01521
LV_01519
LV_01527
LV_00016

Decentralised PV Control

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LV_01523
LV_01521
LV_01519
LV_01527
LV_00016

Centralised PV Control

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LV_01523
LV_01521
LV_01519
LV_01527
LV_00016

Mixed Control (Combined PV and EV Control)

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LV_01523
LV_01521
LV_01519
LV_01527
LV_00016

Influence of adopting PV thermal controllers with OLTC

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LV_01523
LV_01521
LV_01519
LV_01527
LV_00016

Influence of adopting EV charging point management with OLTC

LV_01734
LV_01523
LV_01521
LV_01519
LV_01527
LV_00016
9 References


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Author/s:
Procopiou, AT; Ochoa, LF

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