EXPERIMENTATION OF VOLTAGE REGULATION INFRASTRUCTURE ON LV NETWORK USING AN OLTC WITH A PLC COMMUNICATION SYSTEM

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ABSTRACT

The energy transition comes along with an increase of voltage variations especially on the LV (Low Voltage) network due to photovoltaic (PV) generation influence. In the scope of the French smart grid demonstrator GreenLys, and in order to limit these variations, an OLTC (On Load Tap Changer) has been experimented in a secondary substation in Lyon since November 2015. It has been associated through PLC (Power Line Communication) with several voltage sensors wisely placed on the LV network to get a precise vision of the voltage on the network fed by the transformer.

This paper describes the voltage regulation infrastructure implemented and its main outcomes.

INTRODUCTION

The French Low Voltage (LV) Distribution Networks, operated by Enedis (ex ERDF), supplies 35 million LV customers through 750 000 MV/LV transformers.

The significant increase of distributed generations in the LV network is intensifying the voltage variations with voltage rise due to generation/consumption unbalance during intermittent production.
Furthermore, the development of new usages such as electric vehicle or demand response may increase the consumption peaks and hence, lead to a potential increase of these voltage variations (with potential transit issues as well).

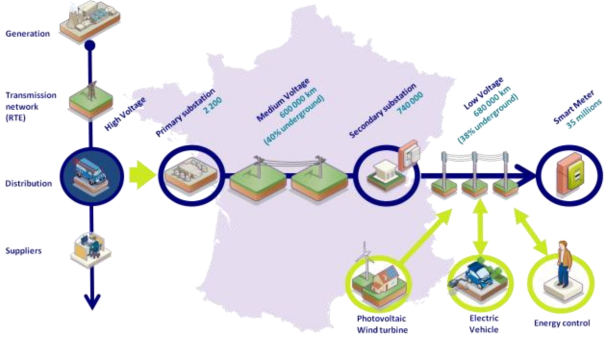


Figure 1 : schematic drawing of networks operated by Enedis

In order to prevent voltage violations (overvoltage or voltage drops) and allow a smoother coordination of MV and LV networks voltages, one potential solution is to locally regulate the voltage on the LV network in alternative to historical grid reinforcements or restructurations. An OLTC (On Load Tap Changer) is a potential mean to reach this goal.

EXPERIMENTATION CONTEXT

GreenLys was a smart grid demonstration project led by Enedis from 2012 to 2016 within ADEME projects (French Environment & Energy Management Agency) framework. It experimented the operation of a smart grid over the whole electricity supply chain. It has taken place in Lyon and Grenoble. In this frame, an OLTC has been experimented in a secondary substation since November 2015. Is has been installed in Confluence, a dynamic district of Lyon. It concerns the LV network fed by a MV/LV transformer in a zone characterized by recent low consumption buildings equipped with solar panels [1].

TECHNICAL ARCHITECTURE IMPLEMENTED

Infrastructure presentation (see fig.2 bellow)

7 sensors have been installed on the LV network in order to capture voltage extrema. The secondary voltage of the transformer is also measured and used for the regulation.

The 7 sensors communicate with the OLTC regulation function by LV PLC. Voltage regulation is either made locally at the MV/LV Transformer station via an automatism or remotely via a dedicated centralized supervision and control system located at Enedis Regional Control Centre. The remote capability is made possible through a MV PLC communication between the secondary substation and the primary substation combined with a GPRS connexion between the primary substation and a remote computer.

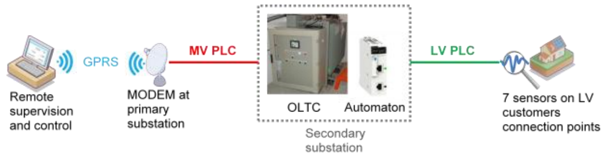


Figure 2 : simplified telecommunication infrastructure

Smart MV/LV transformer (see fig.3, 4 and 5)

The OLTC installed is called “booster” and supplied by Schneider Electric. It has a power of 630 kVA, a primary nominal voltage of 20 kV and a secondary nominal voltage of 420 V. It is equipped with 9 taps of 1.75% step (of the LV nominal voltage).

Figure 3 : installed OLTC picture

The technology developed has been patented and is made of 2 active parts. The first one is the conventional transformation device and the second one is called the booster part:

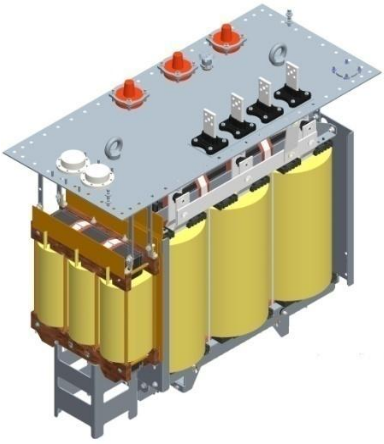


Figure 4 : booster transformer

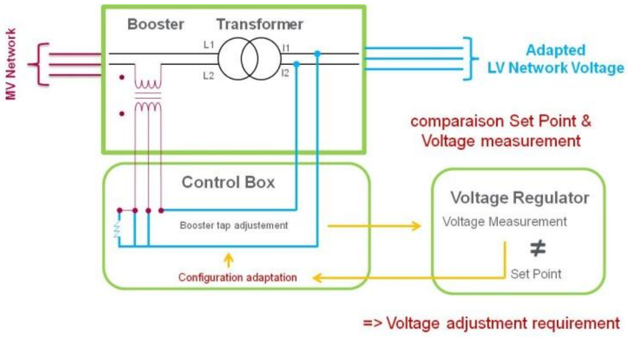


Figure 5 : principle scheme of the booster transformer

This configuration allows low maintenance with high life expectancy (potentially several millions of operations) due to proven LV contactors, with no mechanical parts inside the tank and no power electronics. The level of losses is also low.

PLC

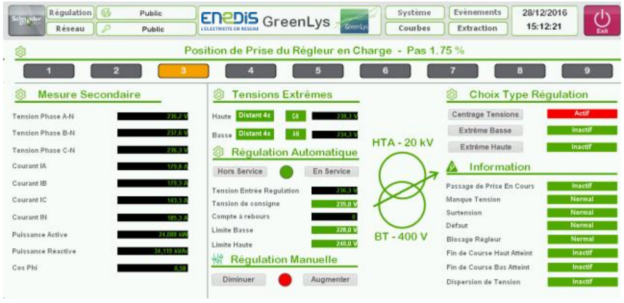
Both MV and LV PLC used in this experiment have been developed by the French start-up WDB and are based on Broadband Power Line UPA/DS2 standards.

The implementation of a robust PLC communication has required taking up some challenges. First of all, the isolation of the capacitive coupler has to respect the MV standards in order to ensure a secure operation at a 20 kV operating voltage. Furthermore, it has to be easily implemented in existing MV installations and not be intrusive. Then, to offer a performing communication, the system must be adapted in impedance to the MV cable to which it is directly connected. Lastly, the different spurious frequencies and harmonics generated in MV cells or other MV equipments have to be correctly modeled and taken into account.

Smart regulation

In addition to the remotely manual control, the transformer embeds the regulation controller allowing local automatic voltage regulations; it is made by an algorithm which determinates the tap change directly from voltage measures. Many strategies of regulation are possible [2]. The basic regulation is traditionally done by measuring and comparing the voltage of the transformer with the reference voltage set by the user; in case of difference, the tap is changed with an optimized algorithm to adjust the output. This basic regulation doesn’t fit well when the decentralized energy production increases and may locally raise the voltage. It is the reason for which 7 measurement points have been added on the LV network.

The implemented regulation consists in keeping the network voltage as close as possible to the reference voltage. Practically, there is a tap change when the average of extrema voltage deviates for more than 0.875% (a half step of a tap, i.e. around 2V) of the reference voltage.



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15:12:21

Position de Prise du Régleur en Charge - Pas 1.75 %

Mesure Secondaire

Tension Phase A-N 236,2 V
Tension Phase B-N 237,6 V
Tension Phase C-N 236,3 V
Courant IA 179,8 A
Courant IB 179,3 A
Courant IC 143,3 A
Courant IN 185,3 A
Puissance Active 24,088 kW
Puissance Réactive 34,119 kVAr
Cos Phi 0,58

Tensions Extrêmes

Haute Distant 4c C6 238,3 V
Basse Distant 4c A8 234,3 V

Régulation Automatique

Tension Entrée Regulation 236,3 V
Tension de consigne 235,0 V
Compte à rebours 0
Limite Basse 228,0 V
Limite Haute 240,0 V

Régulation Manuelle

Choix Type Régulation

Centrage Tensions Actif
Extrême Basse Inactif
Extrême Haute Inactif

Information

Passage de Prise En Cours Inactif
Manque Tension Normal
Surtension Normal
Défaut Normal
Blocage Régleur Normal
Fin de Course Haut Atteint Inactif
Fin de Course Bas Atteint Inactif
Dispersion de Tension Inactif

Figure 6 : remote control HCI (Human-Computer Interaction)

EXPERIMENTATION MAIN RESULTS

General Statistics

The analysis has been made on a 110 days period representative of a whole year operation; following table summarizes the functioning of the OLTC during the experimentation.

Tap position	Duration (in days)	Duration (in %)
Tap 1	1.9	1,7
Tap 2	83.1	75,8
Tap 3	21	19,2
Tap 4	3.6	3,3
Tap 5	0.001	0,0009
Tap 6	0.0003	0.0003
Tap 7	0	0
Tap 8	0	0
Tap 9	0	0
Total	**110**	**100 %**

Figure 7 : duration of taps utilization

On this period, there are around 6 tap changes per day on average, with a minimum of 0 and a maximum of 20.

The first learning is that 9 taps are not necessary for this specific network. For the use case implemented which is keeping the voltage on the network as close as possible to a reference voltage, 3 taps would have been sufficient more than 98% of the time, and 4 taps for more than 99.9% of the time. For another use case closer to DSO (Distribution System Operator) duties, for example avoiding voltage constraints, the number of required taps would be even lower.

The second learning is that the most used tap is the N°2, but it should have been the N°5 in order to totally benefit from the number of taps provided.

Adaptation to voltage variations

The Figure 8 illustrates the behavior of voltage regulation on a regular day. At the end of the morning, the generation increase leads to a voltage rise which is compensated by a pulling down of the tap position. At the end of the afternoon, the production fall drives a voltage fall, and hence the OLTC comes back to its previous tap position before the production peak. During the evening, the production is null, but the 2 hours consumption peak bring about a temporary pulling up of the tap position.

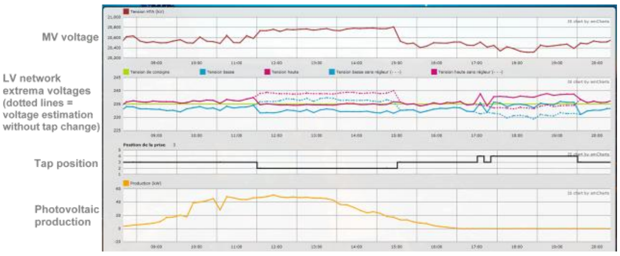

Figure 8 : data collected showing the behavior of voltage regulation on a sunny winter day

This example illustrates that the voltage regulation implemented enables to minimize the voltage variations created by local production and consumption. Another observation has been made: it also permits to isolate the LV network from medium voltage variations.

The Figure 9 and Figure 10 show that on a similar spring day with the same sunlight conditions, the number of tap changes can be very different. The same phenomenon has also been noticed on sunny days, and it can be explained by:

- the threshold effect (a few decivolt can lead to a tap change)
- the impact of LV consumption variations
- the impact of voltage variations of the MV feeder

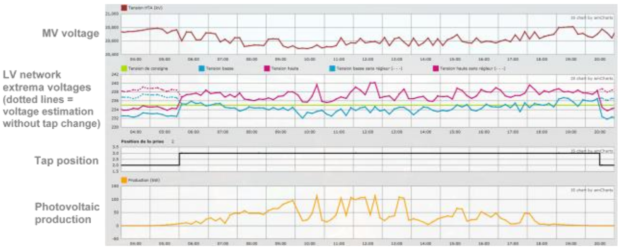

Figure 9 : data collected showing the behavior of voltage regulation on a spring day with variable production.

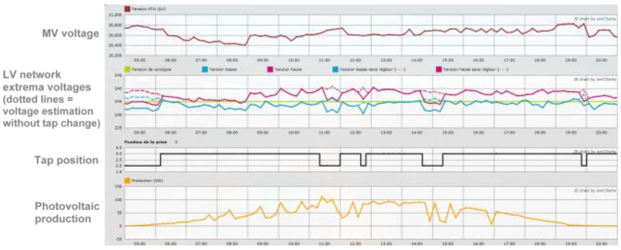

Figure 10 : data collected showing the behavior of voltage regulation on a spring day with variable production.

Potential impact of modified MV operation scheme

A modification of MV network operation scheme had been made for a couple of hours to evaluate the potential impact on voltage regulation: the secondary substation had been fed by another MV feeder from another primary substation. First of all, the supervision and remote control were still possible because the PLC equipments are placed downstream in the MV breaker in the primary substation. Secondly, the voltage regulation was still working, but no tap changes were made. Indeed, the load of the MV network was too low to have a sufficient impact on the voltage seen on the LV network.

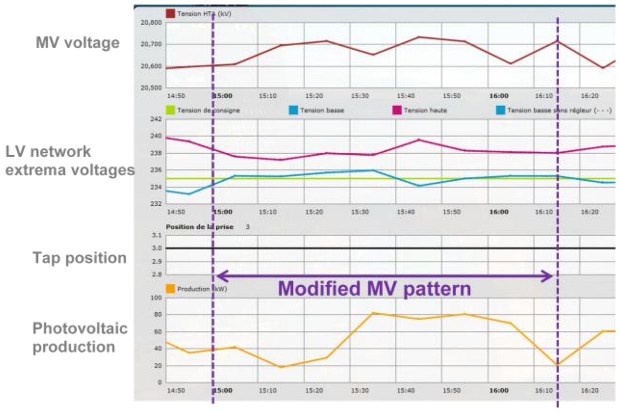

Figure 11 : data collected showing the behavior of voltage regulation during MV pattern (operation scheme) modification

CONCLUSION

The voltage regulation implemented has been proven to be effective. The sensors placed on the LV network enable to have a precise vision of the voltage. The communication by CPL is reliable and offers a high performance for LV network supervision and remote control even with a modified MV operation scheme. Over the year, the voltage regulation compensates the LV consumption and production variations, and the voltage variations of the MV feeder. The voltage regulation with an OLTC associated to sensors communicating by PLC apparently appears to be a solution technically adapted to massive renewable energy integration on the LV network in urban and semi-urban areas. However, its technical and economical interest has to be studied on a case by case basis.

Acknowledgments

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REFERENCES

[1] Jean WILD (Schneider Electric), Yves CHOLLOT (Schneider Electric), Guillaume ROUPIOZ (Enedis), 2015, “Volt var control at the LV distribution level in the Greenlys project”, CIRED Lyon, Paper 1319.

[2] Yves CHOLLOT (Schneider Electric), Christophe LEBOSSE (Enedis), 2015, “New approach to regulate low voltage distribution network”, CIRED Lyon, Paper 1145.