

Energy transition in France: urban communities smart grids integration case

J. Arkhangelski, M. Abdou-Tankari, and G. Lefebvre

Abstract—This research presents an example of the energy transition process application on conventional French urban communities and particularly, its possible integration into the Urban Communities Smart Grids (UCSG). For this, it was chosen one of typical urban community - Alfortville (94140), Paris region, France. The aim is to define all UCSG components and the adapted UCSG structure for the further application of the efficient, renewable, economic and resilient Day-Ahead Optimal Power Flow (DA-OPF) energy management, giving the opportunity to get additional distribution grid flexibility. The integration of UCSG's DA-OPF management requires the centralized control and involves the integration of centralized battery storage systems (CESS) and distributed PV generation. It was determined the optimal penetration rate and size of distributed PV and CESS. The final considered UCSG simplified scheme and its components was defined. The efficient DA-OPF management strategy was applied on the obtained community scheme. The DA-OPF is based on a data forecast system that uses a Deep Learning (DL) Long Short-term Memory network (LSTM) and is formulated as a mathematical Mixed-Integer Nonlinear Programming (MINLP) model. The real data simulation UCSG showed significant benefits and an electricity price reduction for the considered urban community compared to a conventional case, as well as the easy applicability of proposed method. The efficiency and versatility of this research allow its easy application to others similar urban communities under UCSG integration.

Keywords— energy transition, self-consumption, energy management, renewable energy, energy storage, smart grids

I. INTRODUCTION

The energy transition and its socio-economic dynamic create significant challenges to be solved, in

particular on the modes of production, storage and energy consumption. Among the implemented vectors, the significant increase of the penetration rate of Renewable Energies (RE) presents a promising path, notably through the development of distributed production and microgrids.

In this case, national electric grids need much more manoeuvring capacity (flexibility) to offset these effects linked to the penetration of renewable Distributed Energy Resources (DER) and their intermittency. Similarly, Distribution Grid (DG) needs the local reinforcement to meet these challenges, as well as growing demand for electricity. The purpose of this research aims to study this problem of managing the flexibility of electrical grids through the integration of microgrids, especially urban ones, in a process of self-consumption. Flexibility management is achieved through the Day-Ahead Optimal Power Flow (DA-OPF) efficient management. The proposed system iteratively combines Long Short-Term Memory (LSTM) deep learning algorithms and Optimal Power Flow (OPF) methods based on Mixed Integer Non-Linear Programming (MINLP) presented in the previous research [1].

Initially this work presents an example of the energy transition process application on real conventional French urban community of Paris region, France, and particularly, its possible integration into the Urban Community Smart Grid (UCSG). The description of community parameters, the in-deep analysis of its consumption profile, the existing distribution system and the geographic location were presented. Further, it was described the sizing of considered photovoltaic systems, the considered centralized energy storage system (CESS) and Energy Management System (EMS) to create the basis of the UCSG. The choice was justified by several methods and

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techniques. The current research interest to show the technical feasibility and applicability of current government requirements in terms of cost/functionality (necessary minimum), but will require further deeper economic assessment.

In addition to real community data, for practical evaluation was chosen real peak/off-peak hours French electricity pricing also as the flexibility legislation. Additionally, it is considered that the studied UCSG will supply to DG additional flexibility through the Up and Down-regulation Ancillary Service (AS) presented in [2].

The further obtained data processing shows significant benefits and an electricity price reduction for the considered urban community compared to a conventional case, as well as the easy applicability of proposed method. The efficiency and versatility of this research allow its easy application to others similar urban communities under UCSG integration.

Below will be presented one of the possible study case examples of the conventional urban community conversion to the UCSG process for the further application of DA-OPF management with DG flexibility supply.

II. STUDY CASE DESCRIPTION

For the practical evaluation of the developed management system, it was chosen the urban commune of Alfortville (94140), located in the Ile-de-France region, in Val-de-Marne department. Its plan is presented in Fig. 1.

Alfortville is a typical French urban commune of the Metropolis of Greater Paris (MGP). This commune was chosen because of its proximity to the University Paris-Est Creteil (UPEC), the availability of information, as well as the support of this project by the Alfortville city council.

The commune has 44 miles of inhabitants and about 3.67 net square km of the area as shown in Fig. 2.

At the moment, the municipality does not have a considerable RE generation. The aim of this case study is to evaluate one of the possibilities of energy transition for this municipality and bring it towards the goals of the green growth and decarbonization. The experience obtained can then be applied thereafter to other similar urban municipalities in France (77.5% of the population lives in this type of urban communes (2019)) [3].

First, this study begins with the description of this municipality from an energy point of view. According to the main French DG operator Enedis [4], the left side of Fig. 3 shows energy consumption areas and its residential subscriber number (subscribed power). The right part shows the density of annual residential consumption based on location. The exact number of residential customers (electricity delivery points) is 21852 (2020).

According to Enedis "open data" project [5], Alfortville's total annual residential consumption (2019) was 71772 MWh. Fig. 4 presents the annual community consumption profile with a resolution of half an hour.



Fig. 1: Map of Alfortville's location in relation to Paris.



Fig. 2: 2D and 3D view of Alfortville (source [4]).

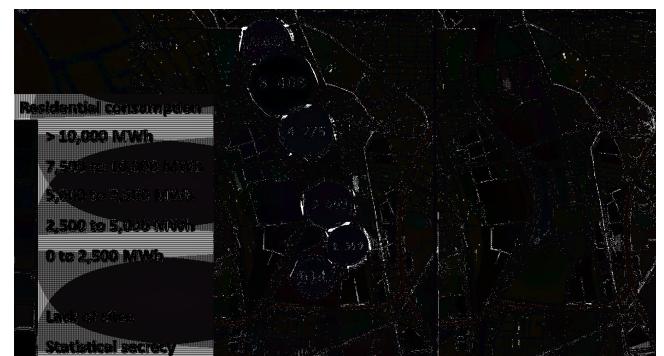


Fig. 3: Electrical consumption and temperature sensitivity by the residential sector: on the right, the distribution of the number of subscribers, on the left energy consumption zones (source [6]).

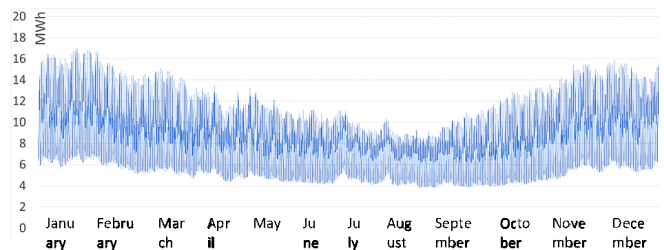


Fig. 4: Alfortville: Annual residential consumption (2019, resolution: half an hour) (source [6]).

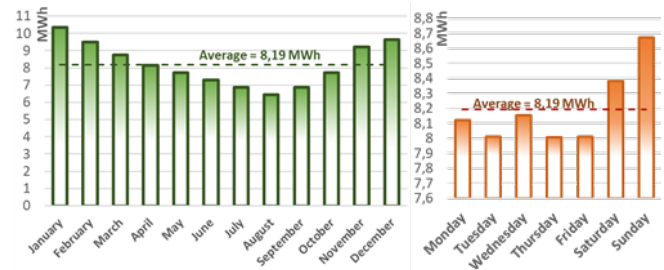


Fig. 5: Alfortville: Distribution of average residential consumption values per month and weekday.

Fig. 5 shows the distribution of the average residential consumption values by month and by the day of the week, compared to the average value.

According to Enedis, Alfortville's distribution network (DG) is shown in Fig. 7 [6]. The Alfortville DG type is radial. First, the network diverges from the main substation (which is located at Ivry-sur-Seine) by Middle Voltage (MV) underground lines, type A (HTA,1.5-75kV

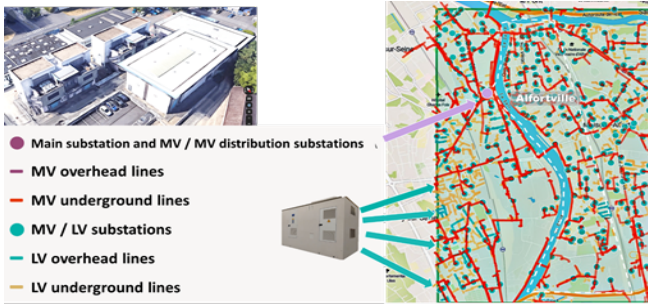


Fig. 7: Mapping of the Alfortville's DG operated by Enedis (source [7]).

AC). These lines join Alfortville via the Seine bridges (Ivry bridge and Port à l'Anglais bridge). Then, several distributed MV/Low Voltage (LV) substations supply consumers via underground LV lines.

After defining the profile of consumption, the work of this research foresees the process of conversion of the urban community Alfortville into UCSG Alfortville. This step will be carried out by installing the DER facilities and community CESS. These actions make it possible to foresee one of the future paths towards energy transition and green growth for French urban municipalities.

A. Choosing a RE system

The concept of energy Penetration Rate (PR) represents the maximum power produced by an energy source in relation to the total power generated. The concept of REs PR represents the maximum power generated by RE, P_{pv}^{PEAK} , in relation to the maximum possible consumption, P_{cons}^{MAX} , how is presented in (1).

$$PP_{ER} = \frac{P_{pv}^{PEAK}}{P_{cons}^{MAX}} \quad (1)$$

Actually, there is no concrete assignments on the parameters of the UCSG Alfortville and the choice of 130% of the PR of the commune is considered optimal (related to bibliographical and practical research) for investment, operation, surface and appropriate benefits as for constant on-grid electrical systems [7]–[9].

The maximum hourly consumption of the municipality Alfortville E_{cons}^{MAX} is equal to 16,2 MWh [5], what corresponds to a peak power $P_{cons}^{MAX} = 16,2MW$ (Fig. 4). For the experimental evaluation, the PV capacity installed in the UCSG Alfortville will be considered according to (2) which is an expression of (1).

$$P_{pv}^{PEAK} = P_{cons}^{MAX} * PR_{ER} = 16,2 MW * 130\% \approx 20 MWp/h \quad (2)$$

In an indicative way, it will be approximately calculated the considered annual PV generation by the CalSol software of the National Solar Energy Institute (INES, *Institut National d'Énergie Solaire*) [10]. 20 MWp of considered PV generation in the Alfortville region represents about 21,564 MWh of annual electric generation (by the weighted average value). This represents around 30% of the total annual community consumption (71,772

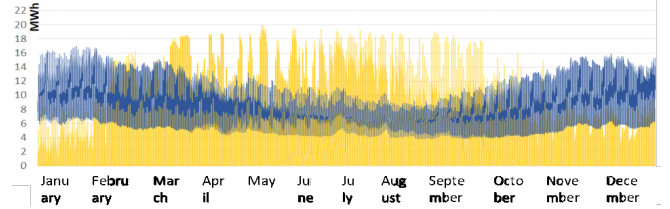


Fig. 6: The consumption and the considered PV generation profile of UCSG Alfortville (2019, resolution: half hour).

MWh). Fig. 6 shows the consumption profile and the obtained considered profile of PV generation.

In the analysis of the data, the concept of Energy Overproduction (EO) is introduced as the difference between generated RE P_{PV} and consumed P_{conso} energy as can be seen in (3).

$$P_{EO} = P_{PV} - P_{conso} \quad (3)$$

The primary analysis of the basic data shows that for this configuration, the PV generation does not exceed community consumption ($P_{EO} < 0$) in 60% during the year under review. For the entire year, the average self-consumption rate is about 90% (minimum value: 70%, maximum value: 100%).

Les P_{50} et P_{90} (et autres P_x) are percentiles [11], useful parameters for understanding how numbers are distributed in a sample (Bayesian credible intervals). In Bayesian statistics, a credible interval is an interval in which an unused parameter value falls with a particular probability.

The description of the most common percentile: the x -th percentile ($0 < x < 100$) a list G ordered values N (sorted from the smallest to the largest) is the smallest value of the list, in such a way that x per cent of the data is less than or equal to that value. This is achieved by first calculating the ordinal rank, n , and then taking the value of the ordered list G which corresponds to this rank. The ordinary rank n is calculated by (4).

$$n = \left\lceil \frac{x}{100} * N \right\rceil \quad (4)$$

The x -th percentile of ordered values P_x is presented in (5).

$$P_x = G[n] \quad (5)$$

Percentile values P_x will be applied in the deep processing of obtained data. The value P_{50} is the centre/average percentile that represents the estimate that occurs with the highest probability, also called "best estimate" and it can be exceeded with a probability of 50%. The P_{90} must be exceeded with a 90% probability and is considered a "cautious estimate".

Fig. 10 shows more precisely the daily non-self-consumed EO for the considered year produced from Fig. 6.

Fig. 11 shows the distribution of overgeneration values based on the number of days. The $P_{EO}^{average}$, P_{EO}^{50} et P_{EO}^{90} from Fig. 10 and Fig. 11 represent respectively the average

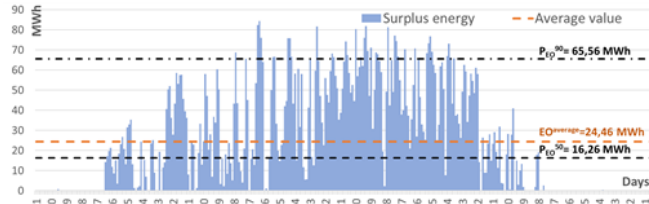


Fig. 10: UCSG Alfortville: The daily energy overgeneration (EO) that is not self-consumed.

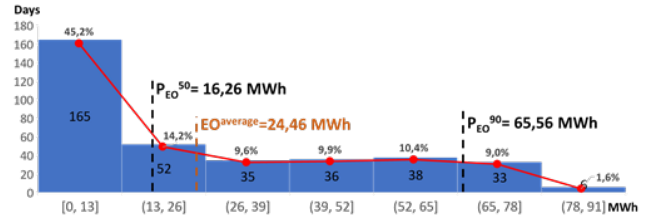


Fig. 11: UCSG Alfortville: The distribution of non-self-consumed values based on the number of days.

annual value, the 50th and 90th percentile of non-self-consumed EO.

In this latter figure, the more likely value of the daily EO (P_{EO}^{50}) is equal to 16,26 MWh. The average EO daily value ($P_{EO}^{average}$) for the year is 24,46 MWh and represents the value of about the 60th percentile (P_{EO}^{60}). In other words, the 60% of non-self-consumption EO values are at least equal to the value $P_{EO}^{average}$. This analysis shows that the system of PV generation according to the PR defined previously, allows in 60% of cases not using the energy storage system.

According to [12], in-depth data processing shows that with the considered PV system of UCSG Alfortville:

- the Degree of Self-Sufficiency is 32.60%.
- the Self-Consumption Rate is 92.81%.
- the Degree of Electrical Autonomy is 35.11%.

The next step is to define the capacity of the considered UCSG Alfortville storage system. Also, the produced above processing of the electrical overgeneration data will help to see and to define the constraints and values of optimal estimation and required storage capacities.

B. Choosing the storage system

In this work, it is considered that the storage system of UCSG Alfortville must provide the community supply during possible serious DG accidents, in other words, it must provide almost continuous supplying [13]. This is related to the fact that this type of urban communities has permanent connection to the DG and not dedicated to full off-grid operation (only in the case of accident in the DG) [14]. In order to define the average duration of serious accidents and thus to size the necessary storage system, it is necessary to study the statistics of accidents and cuts in the DG in France. By Enedis, [15], Fig. 9 and Fig. 8 present the duration and average frequency of LV and MV grid outages.

Statistical data for the past 10 years shows that the value of the maximum duration of the average outage is approximately 70 minutes. The number of cuts is about 3 per year. In the work of this research, this value will be considered as one of the constraints to ensure the UCSG

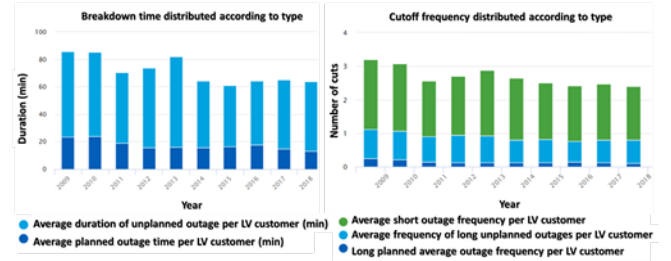


Fig. 9: The duration and average frequency of outages on the Enedis LV network (source [16]).

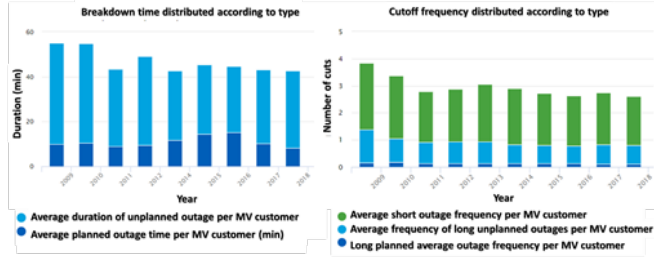


Fig. 8: The duration and average frequency of outages in the Enedis MV network (source [16]).

reliable supply. The required storage system must be able to supply the community in full consumption, for a minimum duration of 70 minutes. The rest of the time, when there are no DG outages, UCSG's storage system will either absorb the RE overgeneration (EO) or will be used to provide the possible flexibility to the DG.

A simple model of related battery in [16] is implemented to evaluate the nominal size of the storage system. The model must take into account the Depth of Discharge (DoD), the Maximum Possible Demand (E_{cons}^{MAX}), Duration of Autonomy (D) and aging. The DoD is optimally selected for each battery to ensure its durability and efficiency. The minimum State of Charge (SOC) is equal to 20% and the maximum SOC to 100% (the DoD is 80%) for Li-ion batteries [17], [18]. These parameters will also have to be taken into account in this study. The demand E_{cons}^{MAX} represents the maximum possible consumption, described in the previous section. It indicates how long the battery is able to meet demand. For this study, this is the average possible cut-off time in the DG of Enedis. Operating temperatures and aging also affect the functioning of the BESS. Therefore, considering the 28°C as the average operating temperature of large-scale BESS, the temperature correction factor is 0.964 [19]. The aging factor for the battery is considered to 15% [20]. The common correction factor C_{ETV} is rated by (6) included in sizing (8). This correction factor takes into account the effect of temperature and aging.

$$C_{ETV} = (0,964 * 1,15) = 1,108 \approx 110\% \quad (6)$$

Battery capacity required in kilowatt-hours E_{batt} (max) is in (7).

$$E_{batt} = \frac{C_{ETV} * P_{cons}^{MAX} * D}{DoD} \quad (7)$$

It is expected that the main requirement is to supply the maximum possible consumption P_{cons}^{MAX} during a 70-minute break is in (8).

$$E_{batt} = \frac{110\% * 16,2MWh * (\frac{70}{60})h}{80\%} = 25,83MWh \approx 25 MWh \quad (8)$$

According to these calculations, the minimum size of CESS to fulfil considered constraints is equal to 25 MWh, with required minimum hourly power supply not less to 22 MW (to keep the power supply during the failure even in the evening peak hour). According to the distribution analysis of the non-self-consumed EO in Fig. 11, this E_{batt} will absorb all of EO in about 61% of cases (equivalent to P_{EO}^{61}). In terms of statistical analysis, this is higher than the "best estimate." This result is in the estimating zone between "best" and "cautious" (between P_{EO}^{50} et P_{EO}^{90}).

In totality, the value E_{batt} defined in (8), allows in 80% of the year not to inject electricity into the DG (not having EO). Based on the estimate of the minimum power requirement and the "confidence" analysis produced above, the 25 MWh value is considered optimal between price, functionality and capacity that meets the above-defined criteria. The CESS is considered the main storage system type of UCSG Alfortville. It was chosen 5 pieces of BESS type "container": Kokam High Power Type KCE-5061 -5 MWh [21].

According to Fig. 7, the Alfortville power system (MV) can be reduced to the form of Fig. 12.

The evaluation scenario considers that the current capacity of the distribution substation MV/MV as well as the MV line to Bus 1 is limited to 15 MW. Due to the upcoming increase in consumption in Alfortville (due to the increase in population for the furthers years), the current distribution system on the MV/MV side will need considerable additional investment. These investments are necessary for the renovation and expansion of the capacity of the main substation station as well as the MV line to Bus 1. Instead, if Alfortville is converted to UCSG Alfortville, this will, on the one hand, allow economic, ecological and constant power supply for the community, and on the other hand, this will allow the community to move forward in the process of decarbonization and energy transition. In other words, this decision would allow the necessary investments to be transferred from support of centralized conventional DG radial system to RE and to the energy transition.

It is considered that the expected PV generation and BESS units of CESS will be distributed in the UCSG Alfortville consumption areas (from Fig. 3). Similarly, it is considered that PV energy, generated and stored, in predominance remains in the local consumption area. In this case, it is expected that the overall PV generation electrical balance not consumed immediately - ΔPV , is on the BUS2. The CESS overall electrical balance - $\Delta CESS$ and consumption, they are connected to the BUS3. This will allow ignoring the DG limits and constraints of the

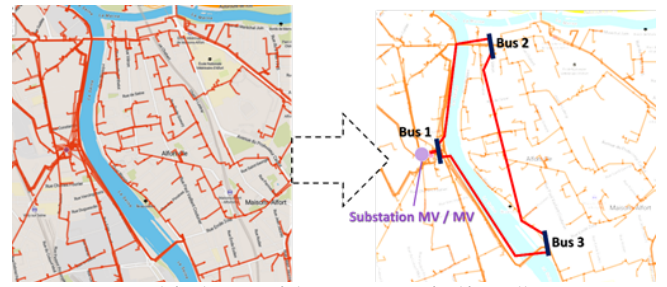


Fig. 12: Simplified view of the DG (MV) of Alfortville (source [7]).

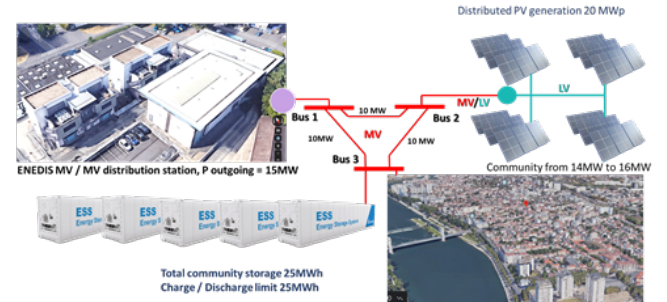


Fig. 13: The synthesized view of the DG of the UCSG Alfortville.

downstream of BUS2 and BUS3. Otherwise, the optimization problem will become much more competitive due to the number of lines and nodes whose data is unknown. Because of the almost uniform distribution of the DER and CESS units in considered consumption areas, it is assumed that the constraints of the existing LV and MV lines on the community territory (downstream of Bus2 and Bus3) also will not be exceeded and they will not be taken into account.

Fig. 13 shows the summarized view of the DG of UCSG Alfortville led to the form for DA-OPF management.

The BESS of CESS will be connected to the already widely deployed MV grid (red lines on Fig. 7 and Fig. 12).

Due to the considerable urban density (seen in Fig. 2), it is planned to install RE generation units on all suitable surfaces of the commune (on the roofs of residential, industrial, public, technical buildings). The generation of RE to be connected in grid MV or LV of the DG (depending on the power of the unit). The LV distribution system as well as the MV/LV substations are already widely deployed in the territory of the municipality (Fig. 7). To mathematically formulate the optimization problem, the configuration of UCSG Alfortville is considered in Table I.

It is expected that with the UCSG conversion, 10% of the

TABLE I
PRACTICAL EVALUATION: UCSG ALFORTVILLE.

Topology	Main triangular grid at 3 buses
Alimentation	Power line at Bus 1, 15 MVA max
Consumption	16,2 MW maximum load on bus 3 10% of load is considered flexible
Branches	BUS1-BUS3 line, limited to 10 MVA
DER	Distributed PV generation (total installed capacity 20 MWp), the overall electrical balance ΔPV at bus 2
CESS	Capacity: 5 units of 25 MWh Maximum total load/discharge rate: 100 MWh, the overall electrical balance $\Delta CESS$ on Bus 3

load becomes flexible: capable of reacting to external signals and able to participate in the different demand

response programs. For the case of actual study, this 10 % of the load will be used for the Up and Down-regulation flexibility service described in [2]. It is considered that the Aggregator reserves 10 MWh of CESS capacity and this capacity consists mainly of the CESS, but can also take into account the residential BESS (if available), which will be managed by the time of the call from the Aggregator. This capacity represents a reserve of 10 MWh of the total 25 MWh of the considered CESS. The remuneration price for this AS is 10 c€/kWh for charged/discharged energy [27].

The mathematical formulation of chosen efficient DA-OPF with the aim of Locational Average Marginal Pricing (LAMP) minimization is presented in [1].

III. PRACTICAL EVALUATION

C. LSTM data forecast

To apply the DA-OPF efficient UCSG management, it is required to make a data forecast and to define the ancillary service participation.

To obtain the UCSG Alfortville data forecast, December 16, 2019, was chosen as the reference D day. In this way, December 17, 2019, is considered the day D+1, for which the DA-OPF is going to be created. The year-end date was chosen because of the most complete use of historical data (the longest available sequence from the beginning of the 2019 year). The forecasting system needs historical values of predictive parameters (consumption, PV generation) and also values of weather data. Weather data were taken from public weather data in France (climate conditions and outside temperatures).

90% of consumption sequence was employed to train the forecast system network and 10% of the latest data in this sequence was used to test the LSTM network [22]. This step is important for adjusting cell weights to help them reconcile differences between actual and expected results. As soon as the process is complete, the forecasting system is then ready to generate forecasts. The input data sequence is set up in this profile way: by entering the D-1 data (community consumption profile from December 15, 2019, with the ambient temperature forecast for December 17, 2019), the forecast system generates the UCSG consumption forecast for D + 1 (December 17, 2019). Fig. 14 and Fig. 15 show profiles of obtained forecasts and real community consumption and PV generation of December 17, 2019.

The expected consumption profile with the integrated Up and Down-regulation (10 MWh) is shown in Fig. 16.

D. DA-OPF

For mathematical formulation, it is necessary to consider the issue of reactive power. The compensation of reactive power is particularly relevant for industrial companies, due to asynchronous machines, induction and arc furnaces, magnetic ballast lamps with fluorescence or discharge, etc. Residential consumers also generate reactive power, but on a much smaller scale. Also, all PV

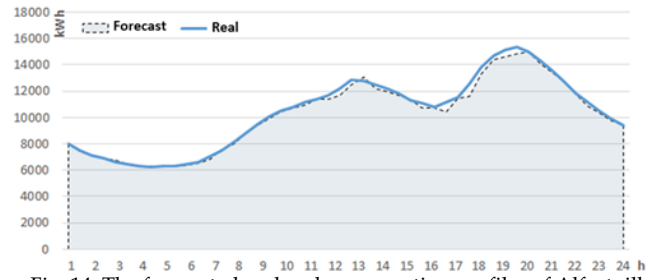


Fig. 14: The forecasted and real consumption profiles of Alfortville for December 17, 2019.

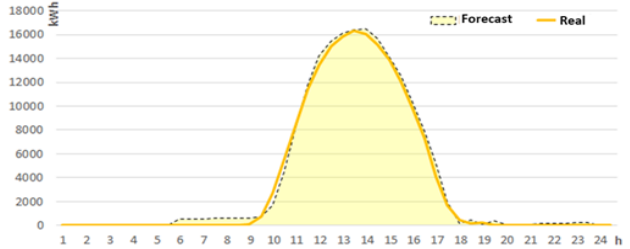


Fig. 15: The planned and real profiles of the Alfortville PV generation on December 17, 2019.

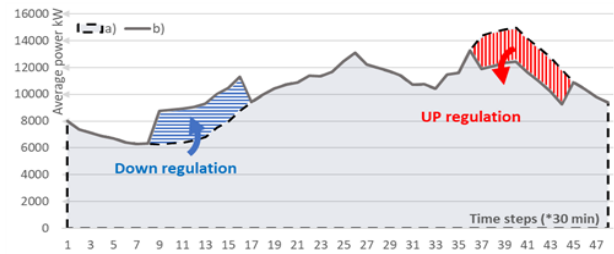


Fig. 16: The projected consumption profile with the integrated Up and Down regulation.

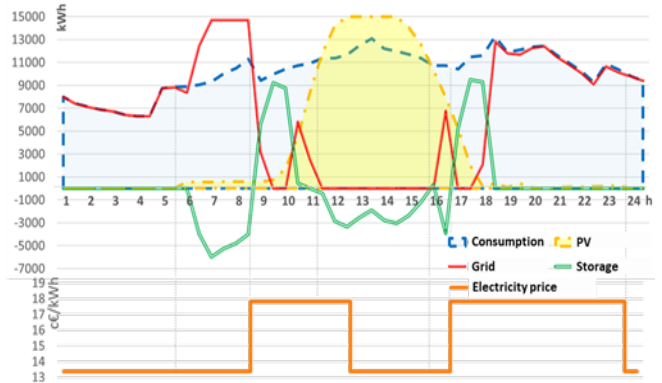


Fig. 17: The predictive DA-OPF strategy for the UCSG management with Up and Down-regulation flexibility.

generation facilities connected to LV or MV generally have an integrated reactive power control system. For the current evaluation, it is considered that reactive power control is imposed on PV and CESS inverters, which are uniformly distributed over community consumption areas. For these reasons, the mathematical formulation of developed OPF considers only active power flows.

shows that for considered day, the OPF contribute to the DG energy use in off-peak hours in the first part of the day. Before the start of the peak hours of the morning, the OPF will charge the CESS as much as possible and then use the stored energy to supply the UCSG consumption of the before the start of the PV generation (energy arbitrage).

Subsequently, when the PV community generation begins, the OPF contributes to storing the excessive PV

generated power in the CESS. Before the start of the evening's peak hours, the OPF plans to charge the CESS as much as possible and also to take advantage of energy arbitrage. In the period of peak evening hours, when the consumption of UCSG increases and the PV generation gradually decreases, the OPF prefers to use the electricity previously stored in the CESS to meet the missing electrical demand, until the storage system is exhausted.

The OPF USCG Alfortville evaluation according to the algorithms presented in [1] with the aim of LAMP minimization is in Fig. 17. It can be seen that for considered day, the OPF uses the CESS to supply the urban microgrid and not to use the DG for the long period of the peak hours (bottom graph). It is noticeable that the DA-OPF optimization significantly reduces the use of DG by minimizing the LAMP of the considered microgrid for each period.

IV. RESULTS ANALYSIS

Fig. 18 shows the evaluation of the considered CESS's SOC during the UCSG operation. As previously stated, the 10 MWh of the capacity of CESS are reserved for AS (Fig. 16) and the remaining 15 MWh was available for the chosen below DA-OPF operating system (indicated as SOC=1 in Fig. 18).

It is noticeable that the CESS makes two cycles of charge/discharge during the day. The OPF prefers to charge the CESS with DG before the first peak hours, and then supply the community with this energy (energy arbitrage). Also, it charges the CESS by the EO of RE with the help of the DG.

Fig. 19 presents the LAMP curve in relation to the price of daily electricity dual pricing. During the afternoon, the value of LAMP is significantly below the electricity price. This effect is achieved through RE generation, storage management, EO flows and energy arbitrage. Table II present operational values for this developed strategy.

The economic analysis is presented in Table III. There are 3 cases of comparison and one "Base" case. This "Base" case describes the Alfortville community operation before the conversion to UCSG Alfortville (without PV generation, CESS, EMS). All the energy to supply the consumption is directly purchased from the DG with the grid price. Case 1 is called the "self-consumption case." Here, the community is converted to UCSG by integrating the PV generation, the CESS and the EMS described previously. The EMS grows the self-consumption. The EO will be stored in the CESS and used during the power supply shortage. As described above, this type of management is widespread and is very common for PV management and storage systems with conventional EMS.

Case 2 is the application of the DA-OPF developed management system without participation in AS (Up and down-regulation). The profile of community consumption is identical to case 1 (Fig. 14). Case 3 is the same as previous but with the participation in AS of flexibility.

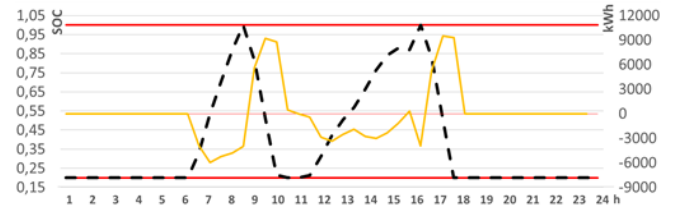


Fig. 18: The operation of CESS (in yellow) and its SOC (in dotted black).

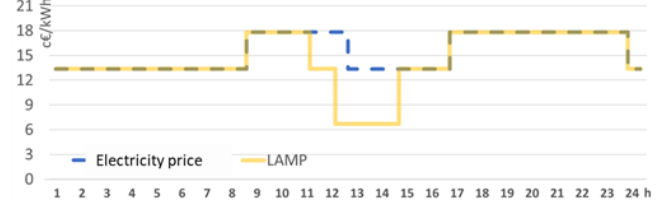


Fig. 19: LAMP evaluation against the dual electricity pricing.

TABLE II
THE OPERATIONAL VALUES OF PRACTICAL EVALUATION

Values (24h)	DA-OPF
PV generation	87314 kW
Total consumption	244992 kW
CESS operation (Charge/Discharge)	-24161/24161 kW
DG operation	157699 kW
Electricity price (average)	15.405 c€/kWh
LAMP (average)	14.43 c€/kWh

TABLE III
ECONOMIC ANALYSIS OF THE UCSG ALFORTVILLE SIMULATION OF OPERATION (DECEMBER 17, 2019).

Case	Total/Average daily community electricity price	Value
Base	Conventional case	38631 € / 15.76 c€/kWh
1)	Self-consumption case	25249 € / 10.31 c€/kWh
2)	DA-OPF without AS	23954 € / 9.77 c€/kWh
3)	DA-OPF with AS	22122 € / 9.02 c€/kWh

The total community daily price of electricity is calculated as follows: the sum of the expenditure of the urban community for the electricity withdrawn from the DG at the DG price (according to the hour) minus the profits of the participation in the AS (if there is any). The value of the average unit community electricity price represents the total daily community price of electricity divided by the total power consumed by the community.

It can be seen that the DA-OPF smart management as well as participation in the AS of flexibility reduces the electricity community price about 7.6% compared to case 2, to approximately 12.3% compared to case 1 and about 42.7% compared to the "Base" case without changing the configuration of the UCSG and for the same operational conditions.

This economic analysis shows that the developed mode of operation, based on data forecasting, non-linear optimization and flexibility, provides additional advantages. It also makes it possible to significantly reduce the community electricity price without changing the configuration of the network and by applying only the "intelligent" mode of management. Among the additional

benefits, on the one hand, the proposed UCSG's participation in the flexibility ASs helps provide additional flexibility to the DG on the other hand. The efficiency and versatility of this research allow its easy application to others similar urban French or foreign communities under UCSG integration.

V. CONCLUSION

This research presents one of the practical examples of the conversion process of one real conventional French urban community to the urban community smart grid. This conversion coupled with the efficient DA-OPF management also as with AS of flexibility participation allows for one side to get closer to the goal of energy transition and to have the economical, ecological and reliable power supply without changing the configuration of the network and by applying only the "intelligent" mode of management. From another side this allows to DG to obtain additional flexibility which it really needs. The efficiency and versatility of this research allow its easy application to others similar French or foreign urban communities under UCSG integration. Proposed research shows the feasibility of a technical point of view but requires further deeper economic assessment.

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