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***Abstract*— The installation of distributed energy resources (DER) heavily impacts on the power patterns of the prosumers. In fact, the variability of the generation, together with the technical characteristics of the storage systems, may introduce a huge variety in the shape of the net power curves seen from the point of common coupling (PCC). This leads to completely rethink the definition of the time series required to create homogeneous group of prosumers, for providing useful tools to manage the emerging paradigms in the electricity system, such as energy communities and local energy markets. Moreover, the differences between the local energy production and consumption at the PCC could become hidden, if the local energy management has to be considered as a private decision of the local user. In this case, only net metering (that implies a unique measurement of the net electricity taken from the grid) will be used to evaluate the impact on the network of the net power curves. Hence, new approaches are required to properly measure the electricity exchange at the PCC. This paper addresses how the net metering outcomes depend on the time resolution of the measured data, and how the information taken from net metering can be valued by giving different price rates to positive and negative values. Specific examples are provided to remark the importance of the time resolution to properly characterise the prosumers.**

***Keywords*— net metering, data analytics, local energy markets, energy communities, prosumer.**

I. Introduction

In the last thirty years, the electricity system changed its paradigms both in terms of sources used and system operation. For example, in Europe the electrical consumption fed by Renewable Energy Sources (RES) reached 30.7% in 2017, by doubling the share of 2005 [1]. The diffusion of RES introduced new challenges, e.g., RES unpredictability. The presence of unpredictable generation from photovoltaic (PV) systems, also available for a limited period during the day, is changing the operation of the network. Hence, intraday periods of analysis have been introduced to better represent the differences among the time intervals during the day, with intraday auctions [2] or continuous intraday markets [3]. Correspondingly, actions on the network structure are required to optimise the intraday distribution system configuration [4]. Considering a larger and larger share of RES, the system could move from the "load-following" paradigm, in which the generation is adapted to follow the evolution of the load, towards the "generation-following" paradigm, in which the load becomes more adaptable to follow the variable generation, with an increasing role of the load side as an active part of the electrical system operation. In particular, the load side is involved also through Demand Side Management (DSM) strategies [5], which include energy efficiency improvement, self-production and electrical load-management [6], and Demand Response (DR) programmes based on incentives or price signals [7,8]. In the general case of prosumers, the DR programmes aim to manage the *net power demand* of the prosumer, seen as the difference between the load and the local generation at the point of common coupling (PCC), also considering the potential presence of storage systems. This is an important aspect, because the engagement of the prosumers into the electrical system management is expected to increase in the future, especially in Europe, where prosumer engagement policies are emerging [9].

Any DR programme needs proper knowledge of the demand side flexibility, defined as the ability of a consumer (prosumer) to deviate from its normal electricity consumption (and production) patterns, in response to price signals or market incentives [10]. Thus, a fundamental feature of the needs to be evaluated is the "responsiveness", i.e., the capability to provide energy (or power) with a well-defined shape in a well-defined time interval [11].

However, the proper implementation of any DR programme needs to consider both technical and non-technical aspects. An important non-technical aspect is that DR programmes require the active engagement of prosumers which partially renounce to their habits. Over-estimating the willingness of the customers to really participate to the DR programme can lead to wrong evaluation on the effectiveness of the programme itself [12]. Other non-technical aspects refer to digital divide and digital illiteracy [13], which can limit the benefits that can be obtained from digital technologies when part of the population has no active role due to limited knowledge on new technologies and tools [9].

On the other hand, some technological aspects can affect the user engagement of these systems, such as [6,14]:

- the proper evaluation of the prosumer baseline, fundamental to determine the service remuneration;
- the presence of energy management systems able to manage the *net power* (not only with passive load, but also with generation and storage facilities);
- the presence of proper measurement devices that record the power curves with sufficient resolution in time [15].

Moreover, if the local energy management has to be considered as a private decision of the local user, the differences between the local energy production and consumption at the PCC could become hidden. In this case, only *net metering* (which implies a unique measurement of the positive or negative net electricity taken from the grid, by using a bidirectional meter [16]) will be used to share information with the supplying entity, and to evaluate the impact on the network of the net power curves. In this case,

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new approaches are required to properly measure and elaborate the electricity exchange at the PCC.

The above aspects assume higher relevance for integrated energy systems [17], such as energy communities [18]. In this case, the data related to the energy consumed and produced by the different energy community members assume a key importance to study internal remuneration strategies. With net metering, the net energy exported to and imported from the grid in a specific time period may be subject to different economic rates, thus providing margins of convenience depending on the economic rate variation. Net metering has been found interesting for residential applications [16,19], and is one of the viable options for sharing the electricity generated by PV systems of different prosumers [20].

On these bases, this paper aims to show that the nature of the data is crucial to properly evaluate the role of any member of the energy community, also when net metering is applied. Various aspects referring to the time resolution of the data are addressed. For instance:

- the way to represent the power patterns has to be carefully explained, to avoid the introduction of artificial delays in the representation;
- different data representations of the same net power pattern, such as stair-wise or with interpolations, have to be carefully defined in order to provide the same total energy in the time period represented;
- starting from power patterns having hourly time samples (as it is common for renewable resources time series), the attempt to create patterns with lower time sample to fit with load patterns (for example measured every 5 minutes) can lead to wrong evaluations of the net power;
- appropriate features, which take into account the duration curve of the net power, are defined by separating the positive and negative net powers, considering different price rates for positive or negative net power.

The next sections of the paper are organised as follows. Section II recalls the energy community concepts, to which net metering aspects are relevant. Section III points out specific aspects of the power curve representations at different time steps. Section IV discusses the importance of the net power pattern shape, also with reference to possible different price rates associated to positive and negative net power patterns. The last section contains the conclusions.

II. Energy Community Concepts

In the European Community framework, two different definitions of "energy communities" do exist [21]:

1. *Citizen energy community (CEC)*, defined as a legal entity based on voluntary and open participation, which is actually controlled by the members. The possible members are natural persons, local authorities (including municipalities), or small enterprises. The CEC goal is to provide benefits to its members or stakeholders in the area where it operates, rather than generate financial profits. Finally, it can engage in generation its members or provide energy services to them [22].
2. *Renewable energy community (REC)*, almost equivalent to the CEC, but with an additional constraint linked to the proximity of the renewable energy project owned and developed by the REC. Another aspect highlighted is that the REC has to be established in accordance with the applicable National law [23].

It is evident that the two definitions indicate the open and voluntary participation and the share of the benefits among the members. The presence of large PV plants on one side, and a number of customers that cannot install them on the other side, is a convenient mix to efficiently exploit the generated energy within an energy community, especially if associated to storage systems [24,25]. Any energy exchange among different sites belonging of the energy community has to be analysed by considering the net power available at each site and the timings of the power provision. In this respect, the time steps used for representing and analysing the data, as well as the electricity price rates used for positive and negative net power exchanges at each site, have a crucial impact on the value of the energy exchanges.

III. On the Use of Patterns with Different Time Steps

This section presents some particular cases that can lead to incorrect evaluation of the contribution that the member of the energy community can provide. Let us consider the time step τ. The data used are related to the load pattern $\mathbf{p}_{load,\tau}$ and the PV production pattern $\mathbf{p}_{\mathrm{PV},\tau}$, obtained by applying the procedure shown in [26] to measure load and PV production with different time steps. This preliminary action is necessary to start from sets of data based on patterns with the same time step τ. From these data, two patterns with $\tau_i > \tau$ are built, called $\mathbf{p}_{\mathrm{load},\tau_i}$ and $\mathbf{p}_{\mathrm{PV},\tau_i}$ for the load and the PV generation, respectively. Considering the time horizon T, the corresponding entries are calculated as follows:

$$p_{\mathrm{load},\tau_i}(j) = \sum_{k=1}^{\tau_i/\tau} p_{\mathrm{load},\tau}(k) \cdot \frac{\tau}{\tau_i}, \text{ with } j = 1, \ldots \frac{T}{\tau_i} \quad (1)$$

$$p_{\mathrm{PV},\tau_i}(j) = \sum_{k=1}^{\tau_i/\tau} p_{\mathrm{PV},\tau}(k) \cdot \frac{\tau}{\tau_i}, \text{ with } j = 1, \ldots \frac{T}{\tau_i} \quad (2)$$

The consistency condition to be satisfied is that T is a multiple of both τ_i and τ, in such a way that no unused data remains at the end of the time horizon. In the specific case considered in this section, τ=5 min, τ_i=60 min, and T=43200 min (i.e., one month), hence T/τ_i=720.

The average power entries $p_{\mathrm{load},\tau_i}(j)$ and $p_{\mathrm{PV},\tau_i}(j)$ are constant in the time interval τ_i, and are energetically equivalent to the energy consumed or produced in τ_i by considering the set of values of the original patterns $p_{\mathrm{load},\tau}(k)$ and $p_{\mathrm{PV},\tau}(k)$ existing in τ_i.

These two new patterns emulate a collection of data used to describe, in approximate way, the energy consumption and the energy production for one member of the energy community. In other words, it is supposed that the only known information regarding the prosumer is represented by $\mathbf{p}_{\mathrm{load},\tau_i}$ and $\mathbf{p}_{\mathrm{PV},\tau_i}$, whereas $\mathbf{p}_{\mathrm{load},\tau}$ and $\mathbf{p}_{\mathrm{PV},\tau}$ represent the "actual" behaviour, used as the benchmark.

However, the available information (i.e., $\mathbf{p}_{\mathrm{load},\tau_i}$ and $\mathbf{p}_{\mathrm{PV},\tau_i}$) could be used in an inappropriate way. For example, these vectors could be used to find a representation of the behaviour of the prosumer at higher resolution.

Thus, by starting from $\mathbf{p}_{\mathrm{load},\tau_i}$ and $\mathbf{p}_{\mathrm{PV},\tau_i}$, two more patterns are created, called respectively $\mathbf{p}_{\mathrm{load},\tau_o}$ and $\mathbf{p}_{\mathrm{PV},\tau_o}$, for the time step $\tau_o < \tau_i$. These two patterns have the same resolution in time as the benchmark patterns (in this paper $\tau_o = \tau$= 5 min).

Two main problems arise:

1. The variation of the time steps and the following scaling of the pattern values could lead to a wrong evaluation of the energy associated to the pattern. This would be an

issue, because the variation of the time step in an energy-related pattern must not change the information related to the energy that it represents [26].

2. The variation of time steps will change in any case the shape of the pattern, and this can be visualised by showing the empirical cumulative distribution function (ECDF) of the power variations.

The impact of the first problem can be evaluated through the ratio ζ between the energy of the original pattern and the energy of the derived pattern, i.e.:

$$\zeta = \frac{E_{original}}{E_{derived}} \tag{3}$$

The factor ζ is used as the *scale factor* that multiplies the derived pattern, in such a way that its area represents the same energy of the original pattern.

A. Data representations with different time resolution

Starting from the available data (with τ_i=60 min) the new patterns with τ_o = 5 min are obtained through *linear interpolation*, by placing the points that represent the patterns $\mathbf{p}_{\text{load},\tau_i}$ and $\mathbf{p}_{\text{PV},\tau_i}$ in the centre of the time interval. Using quadratic or cubic interpolations instead of linear interpolation would have no advantages, because the relevant quantity is energy (i.e., the area corresponding to the time step), and not the details of the power pattern shape. In addition, the use of quadratic or cubic interpolations would not improve the situation concerning the discontinuity in the slope of the pattern at the end of each time step.

The linear interpolation procedure needs an initial point that represents the load before the period considered, as well as a further point to represent the next period with respect to the period under analysis. Each result of the interpolation is then interpreted as a load point representative of the time interval τ_o, placed in the centre of this interval. For a daily pattern that starts at the beginning of the day, this aspect is instead not relevant for the PV pattern because, thanks to the day-night cycle, both the preceding and successive points are characterised by null generated power.

The variation of the time resolution affects the value of the energy of the pattern, as shown in Table I.

The load patterns for the monthly time horizon *T*, namely $\mathbf{p}_{\text{load},\tau}$, $\mathbf{p}_{\text{load},\tau_i}$, and $\mathbf{p}_{\text{load},\tau_o}$, are shown in Fig. 1, whereas the corresponding patterns for the PV production corresponding to the same time horizon are shown in Fig. 2. It is worth noting that the pattern of Fig. 1 takes into account also the energy correction (ratio ζ). The zooms of the set of patterns for both the load and the PV generation between the time step at *t*=15840 min and the time step at *t*=17280 min are shown in Fig. 3 and Fig. 4, respectively.

It is evident that the pattern $\mathbf{p}_{\text{load},\tau_i}$, due to the longer time step, is not able to represent the real behaviour of the actual pattern $\mathbf{p}_{\text{load},\tau}$. The same issue arises also for the PV pattern, for which the pattern $\mathbf{p}_{\text{PV},\tau_i}$ only provide rough information regarding the pattern shape, while the fast variations are completely lost. Moreover, Fig. 3 and Fig. 4 show that the attempt to reconstruct the original data, represented by the patterns $\zeta \cdot \mathbf{p}_{\text{load},\tau_o}$ and $\mathbf{p}_{\text{PV},\tau_o}$, does not succeed, because the reconstructed patterns obtained by the patterns $\mathbf{p}_{\text{load},\tau_i}$ and $\mathbf{p}_{\text{PV},\tau_i}$ cannot represent the initial ones.

TABLE I. SCALE FACTORS RELATED TO THE RECONSTRUCTED PATTERNS

pattern	Energy (MWh)	ζ		Energy (MWh)	ζ
$\Delta\mathbf{p}_{\text{load},\tau}$	0.1803	-	$\Delta\mathbf{p}_{\text{PV},\tau}$	0.954	-
$\Delta\mathbf{p}_{\text{load},\tau_i}$	0.1803	1	$\Delta\mathbf{p}_{\text{PV},\tau_i}$	0.954	1
$\Delta\mathbf{p}_{\text{load},\tau_o}$	0.1800	1.001	$\Delta\mathbf{p}_{\text{PV},\tau_o}$	0.954	1

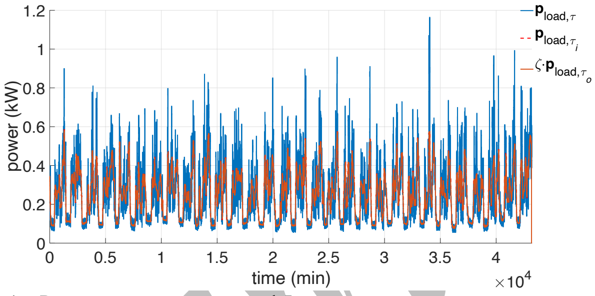

Fig. 1. Patterns $\mathbf{p}_{\text{load},\tau}$, $\mathbf{p}_{\text{load},\tau_i}$ and $\zeta \cdot \mathbf{p}_{\text{load},\tau_o}$.

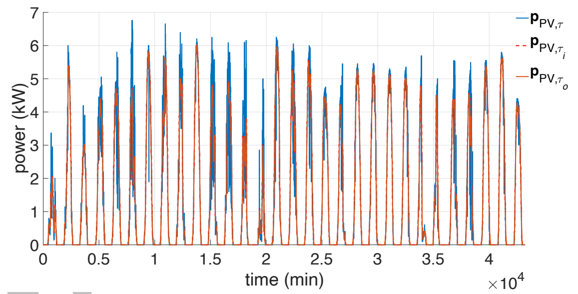

Fig. 2. Patterns $\mathbf{p}_{\text{PV},\tau}$, $\mathbf{p}_{\text{PV},\tau_i}$ and $\mathbf{p}_{\text{PV},\tau_o}$.

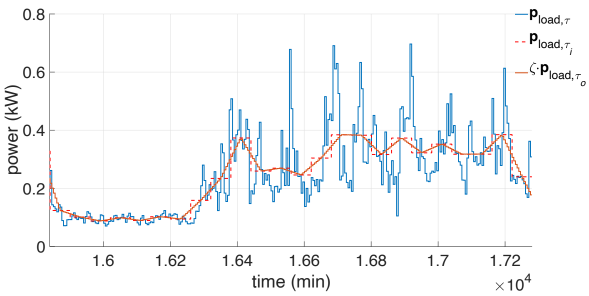

Fig. 3. Zoom of the patterns $\mathbf{p}_{\text{load},\tau}$, $\mathbf{p}_{\text{load},\tau_i}$ and $\mathbf{p}_{\text{load},\tau_o}$.

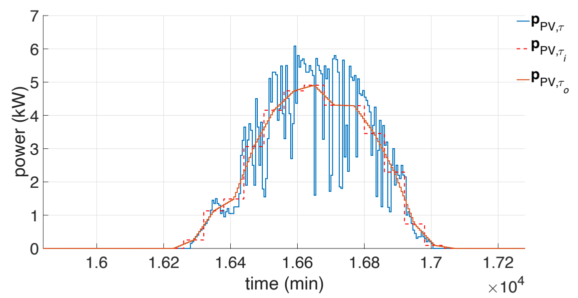

Fig. 4. Zoom of the patterns $\mathbf{p}_{\text{PV},\tau}$, $\mathbf{p}_{\text{PV},\tau_i}$ and $\mathbf{p}_{\text{PV},\tau_o}$.

B. Comparison of the shapes of the patterns

The importance of the shape of the power curves is highlighted in Fig. 5 and Fig. 6, which show the Empirical Cumulative Distribution Function (ECDF) of the *power variations* occurring by moving from the *j*-th time step to the next one. Without loss of generality, by considering the actual load pattern $\mathbf{p}_{\text{load},\tau}$ every component of the power variation vector $\Delta\mathbf{p}_{\text{load},\tau}$ is calculated as follows:

$$\Delta p_{\text{load},\tau}(k) = p_{\text{load},\tau}(j+1) - p_{\text{load},\tau}(j) \qquad (4)$$

with $k = 1, \ldots \frac{T}{\tau} - 1$ and $j = 1, \ldots \frac{T}{\tau}$. Analogously, the pattern $\Delta\mathbf{p}_{\text{load},\tau_i}$, $\Delta\mathbf{p}_{\text{load},\tau_o}$ and the three variation patterns corresponding to the PV generation are created.

Fig. 5 and Fig. 6 show that the ECDFs are quite different, because the variations $\Delta\mathbf{p}_{\text{load},\tau_o}$ and $\Delta\mathbf{p}_{\text{PV},\tau_o}$ depend on the pattern reconstruction, which by definition cannot reproduce the actual variations in the patterns at the same time step in $\Delta\mathbf{p}_{\text{load},\tau}$ and $\Delta\mathbf{p}_{\text{PV},\tau}$ (shown in blue colour). On the other hand, the variations occurring at longer time steps cannot follow the details of the actual patterns. Thereby, the reconstructed patterns cannot represent the actual one.

C. Effect on the net load

The problems highlighted in Section III.B are amplified when the variable of interest is the *net load*, defined as the *difference between the passive load and the local generation* referring to the single prosumer, i.e. (written in the case of time step τ, without loss of generality):

$$\mathbf{p}_{\text{netload},\tau} = \mathbf{p}_{\text{load},\tau} - \mathbf{p}_{\text{PV},\tau} \qquad (5)$$

Fig. 7 shows that the three patterns have different shapes. The effect of the different time resolutions is more evident by considering the power in the cases shown in Fig. 8. By zooming in the interval [19350,19500] minutes, it is evident that the succession of positive and negative values changes by varying the time step (Fig. 9). Also in this case, the ECDFs of the net load variations show that the attempt to represent the initial pattern is not satisfactory (Fig. 10).

IV. The Importance of the Pattern Shape

As demonstrated in the previous section, the importance of the power pattern shape is evident, especially in case of simultaneous presence of both generation and load.

Thus, this section aims to present an alternative method to reproduce the consumption and PV production patterns based on the available measurement. The idea is to find a way to construct a realistic shape of the patterns.

A. Methodology

The rationale of the methodology described in this section is to formulate a procedure to construct patterns with higher resolution in time with respect to the available patterns. The crucial aspect is that the constructed net load pattern should have statistical properties similar to the ones of known net load patterns of comparable type and size. However, the net load pattern is not constructed directly, but is obtained from the load and local generation patterns, each one built separately. This approach has been used in [27] for the load patterns and is followed here also for PV generation patterns. Then, the net load is obtained from (5) by using the time step of interest.

For the sake of simplicity, and without loss of generality, in this section the available patterns are obtained in the same way applied above: starting from the "actual" patterns $\mathbf{p}_{\text{load},\tau}$ and $\mathbf{p}_{\text{PV},\tau}$, with $\tau = 5$ min, the patterns with longer time step

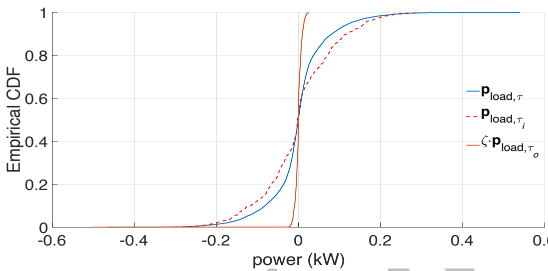

Fig. 8. ECDF of $\Delta\mathbf{p}_{\text{load},\tau}$, $\Delta\mathbf{p}_{\text{load},\tau_i}$ and $\Delta\mathbf{p}_{\text{load},\tau_o}$.

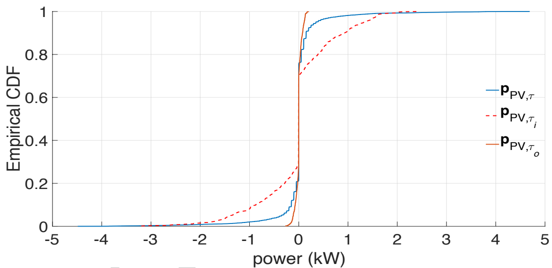

Fig. 9. ECDF of $\Delta\mathbf{p}_{\text{PV},\tau}$, $\Delta\mathbf{p}_{\text{PV},\tau_i}$ and $\Delta\mathbf{p}_{\text{PV},\tau_o}$.

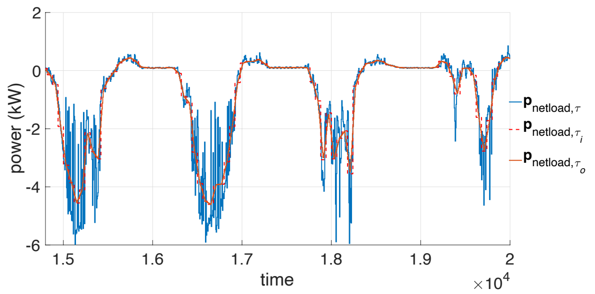

Fig. 10. Patterns $\mathbf{p}_{\text{netload},\tau}$, $\mathbf{p}_{\text{netload},\tau_i}$ and $\mathbf{p}_{\text{netload},\tau_o}$.

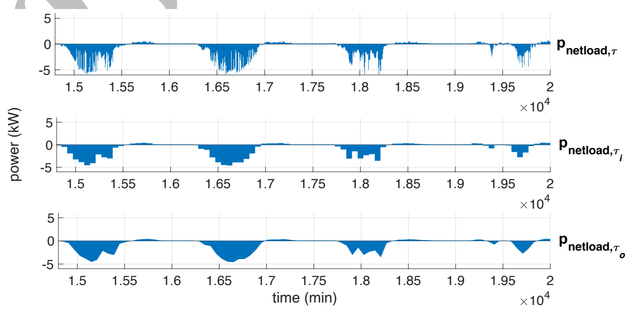

Fig. 5. Power related to the net load, for $\tau = \tau_o = 5$ min and $\tau_i = 60$ min.

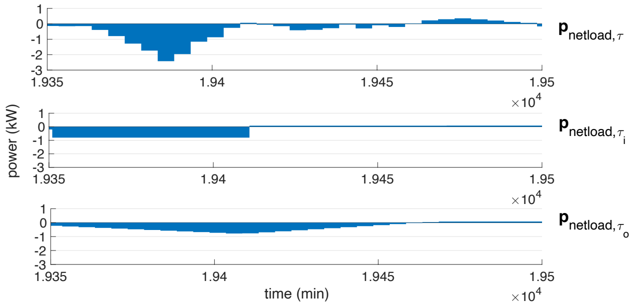

Fig. 6. Power related to the net load for $\tau = \tau_o = 5$ min and $\tau_i = 60$ min.

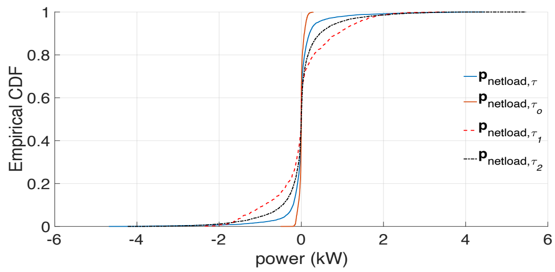

Fig. 7. Empirical CDF related to the net load.

(one hour) are formed and are considered as available patterns (the "actual" patterns remain hidden). Then, the proposed approach is applied to reconstruct separately the load and PV generation patterns at time step of 5 min. The statistical properties used during the reconstruction are taken from the power variations of the "actual" patterns (in this case, not from other similar patterns). Next, the reconstructed net load patterns at time step of 5 min are determined. Finally, the results of the reconstructed and "actual" net power patterns are compared, also in terms of statistical properties.

Starting from the above patterns, four more patterns are created:

- $\mathbf{p}_{\text{load},\tau_1}$ and $\mathbf{p}_{\text{PV},\tau_1}$, with τ_1 =60 min, obtained by calculating the average power that represents the *hourly energy* by starting from the data measured at τ =5 min.
- $\mathbf{p}_{\text{load},\tau_2}$ and $\mathbf{p}_{\text{PV},\tau_2}$, with τ_2 =5 min, which is created by starting from the *power variations occurring in the hours with respect to the hourly mean values.*

It is worth noting that the values contained in the patterns $\mathbf{p}_{\text{load},\tau_1}$ and $\mathbf{p}_{\text{PV},\tau_1}$correspond to the ones collected in $\mathbf{p}_{\text{load},\tau_i}$ and $\mathbf{p}_{\text{PV},\tau_i}$, but are conceptually different. In fact, while $\mathbf{p}_{\text{load},\tau_i}$ and $\mathbf{p}_{\text{PV},\tau_i}$ represented the *available measurements*, the pattern $\mathbf{p}_{\text{load},\tau_1}$ and $\mathbf{p}_{\text{PV},\tau_1}$ represent the *elaboration of the available measurements.*

By considering a time horizon *T*, without loss of generality, the mathematical formulations are shown by considering the load patterns:

$$p_{\text{load},\tau_1}(i) = \sum_{k=1}^{\tau_1/\tau} p_{\text{load},\tau}(k) \cdot \frac{\tau}{\tau_1}, \text{ with } i = 1,\dots \frac{T}{\tau_1} \quad (6)$$

$$p_{\text{load},\tau_2}(z) = p_{\text{load},\tau_1}(i) + \Delta p_{\text{load}}(z), \text{ with } z = 1,\dots, \frac{T}{\tau_2} \quad (7)$$

The value of $\Delta p_{\text{load}}(z)$ is evaluated through a probability-based method [27]. The values of the pattern $\mathbf{p}_{\text{load},\tau_1}$ are divided into *N* classes: in this way, any t-uple of the initial pattern $\mathbf{p}_{\text{load},\tau}$ (composed of ${}^{\tau_1}/_{\tau}$ entries) can be linked to a particular class. Thanks to this, it is possible to build the pattern $\Delta\mathbf{p}_{\text{load},\tau}^{(n)}$ referring to the class *n*, whose entries are calculated as follows:

$$\Delta p_{\text{load},\tau}^{(n)}(z) = p_{\text{load},\tau}(z) - p_{\text{load},\tau_1}(i) \quad (8)$$

Hence, the ECDFs for all the *N* classes formed by the entries of $\Delta\mathbf{p}_{\text{load},\tau}^{(n)}$, *n*=1,…,*N* are built.

Through the extraction of a random number from a uniform distribution and entering into the ECDFs of $\Delta\mathbf{p}_{\text{load},\tau}^{(n)}$, the randomly chosen value of $\Delta p_{\text{load}}(z)$ is calculated.

The same procedure is applied to the PV generation patterns. At the end of this process, the reconstructed net power pattern is obtained from

$$\mathbf{p}_{\text{netload},\tau_2} = \mathbf{p}_{\text{load},\tau_2} - \mathbf{p}_{\text{PV},\tau_2} \quad (9)$$

B. Results on reconstructed net load patterns

The approach introduced is able to reproduce the "actual" pattern in a satisfactory way, as shown in Fig. 11 referring to one day (from *t*=15840 min to *t*=17280 min). The new pattern $\mathbf{p}_{\text{netload},\tau_2}$ is not overlapped to the original one $\mathbf{p}_{\text{netload},\tau}$ (reaching the overlapping is not the objective of this analysis) but is able to better reproduce the *variability* of the net load than the other reconstructed patterns. This aspect is highlighted in Fig. 12, where the ECDFs of the variations is reported: the new pattern $\mathbf{p}_{\text{netload},\tau_2}$ is the most similar, in statistical terms, to the "actual" pattern $\mathbf{p}_{\text{netload},\tau}$.

C. Economic aspects

The impact of the time resolution in the pattern reconstruction may be highlighted in economic terms as well. Let us introduce the price rates ν_{load} and ν_{PV} associated to the passive load and the PV production, respectively. For the sake of clearness, these price rates, expressed in mu/MWh (where "mu" means monetary units), are considered constant along the entire time horizon: this choice has been made to highlight the effect of the different time resolution, without introducing an additional degree of freedom related to the different prices in different time steps. A passive load price rate ν_{load} = 1 mu/kWh is introduced and three cases are investigated:

- Case 1: $\nu_{\text{PV}} = \nu_{\text{load}} = 1$ mu/kWh
- Case 2: $\nu_{\text{PV}} = 0.8$ mu/kWh $< \nu_{\text{load}}$
- Case 3: $\nu_{\text{PV}} = 1.2$ mu/kWh $> \nu_{\text{load}}$

The net PV generation provides an income equal to the net energy generated times the price rate ν_{PV}, whereas the excess of net load originates an expense equal to the net load energy times the price rate ν_{load}. Table II shows the value of positive and negative energy with the "actual" and reconstructed patterns, as well as the profits (i.e., incomes minus expenses) associated to these patterns.

The results show that the change of the time resolution affects the positive and negative energy and impacts on the total profitability associated to the prosumer. Thus, with a

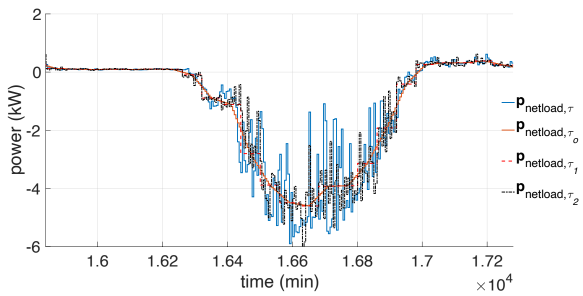

Fig. 11. Patterns $\mathbf{p}_{\text{netload},\tau}$, $\mathbf{p}_{\text{netload},\tau_o}$, $\mathbf{p}_{\text{netload},\tau_1}$ and $\mathbf{p}_{\text{netload},\tau_2}$

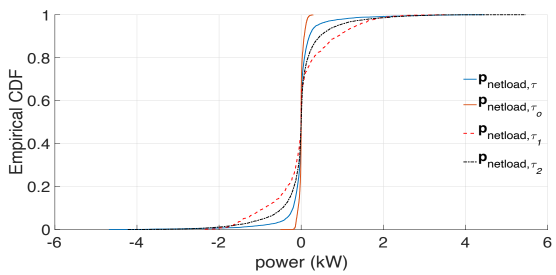

Fig. 12. Empirical CDF related to the net load, comparing the different reconstructed patterns.

TABLE II. ECONOMIC ASSESSMENT

Pattern	Positive Net Load Energy (kWh)	Negative Net Load Energy (kWh)	Profit Case 1 (mu)	Profit Case 2 (mu)	Profit Case 3 (mu)
$\mathbf{p}_{\text{netload},\tau}$	80.54	854.58	774.0	603.1	945.0
$\mathbf{p}_{\text{netload},\tau_o}$	72.29	849.33	774.0	604.2	943.9
$\mathbf{p}_{\text{netload},\tau_1}$	77.84	851.89	774.0	603.7	944.4
$\mathbf{p}_{\text{netload},\tau_2}$	80.80	854.85	774.0	603.1	945.0

simple example it has been clearly shown that the reproduction of the prosumer behaviour needs detailed information regarding the pattern shape. In the absence of data with better time resolution, the pattern $\mathbf{p}_{\mathrm{netload},\tau_2}$ (which incorporates the statistical properties of the original profile) obtained with the proposed procedure is able to reproduce in a reasonably good way the energy of the "actual" patterns, and hence also the income, expenses, and associated profit. These properties may be exploited for assessing the prosumer performance, by using as input data the information of the PV production typical of the zone where the prosumer is placed, and a load pattern representative of the consumption of that type of prosumer.

By starting from load patterns with sufficient time resolution, it could be possible to replicate the statistical properties of the net load, with an additional value in the prosumer characterisation.

V. Conclusions

This paper has investigated some aspects related to the time resolution of the net load patterns. By starting from known patterns with high time resolution, some manipulations have been carried out to emulate the existence of available data with lower time resolution and the successive transformation to patterns with higher time resolution to investigate the features of load and PV generation patterns.

The approach based on linear interpolations resulted unsatisfactory to reproduce the behaviour of the patterns for net power analysis. Hence, a novel methodology based on the exploitation of the statistical features of the actual patterns has been proposed. By starting from load and PV generation patterns with high time resolution, the statistical features of the power variations have been calculated and properly exploited to reconstruct load and PV generation patterns at the same time resolution. The net load patterns have then been reconstructed.

The new methodology resulted satisfactory in reproducing the variability of the actual net load patterns, and this led to similar outcomes from the economic assessment for the actual pattern and the reconstructed one.

The proposed procedure is relevant to an energy community, because the participation of every member of the community has to be properly evaluated. This aspect may be even more important in case of distributed ledgers (like the one based on the blockchain technology), where the transparency of the economic transactions is one of the pillars on which an energy community is founded. In fact, the absence of an independent operator implies the complete collaboration among the community members, and only the detailed knowledge of the real net load, and its proper evaluation in the planning phase, can guarantee the correct participation of consumers and prosumers in the energy community operation, and the assessment of the benefits that can be directly obtained.

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