The Italian reform of electricity tariffs for non household customers: the impact on distributed generation and energy storage

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Abstract: The Italian legislative decree 210/2015, converted into law 21/2016 (known as *Milleproroghe Decree*) sets out that the regulatory authority for electricity, gas and water must re-determine by January 2018 the structure of the electricity tariff components related to the system costs applied to non household customers. The objectives of this reform are: (i) promote more efficient consumption practices, currently penalized by unattractive electricity tariffs, (ii) simplify the electricity bills, making them more readable, (iii) make the system costs more adherent to the actual dispatching costs and (iv) reduce the dependence of these costs from the energy demand. Currently, three different hypotheses have been formulated and are still under discussion. All of them propose a trinomial structure, made up of a fixed part and of two variable components, defined respectively as a function of the peak power demand and of the energy demand. The main purpose of this contribution is to investigate how the reform of the electricity tariffs could affect the diffusion of Energy Storage Systems (ESS) in support of Distributed Generation (DG) based on Renewable Energy Sources (RES). ESS have recently been subject of great interest among the energy market, due to their possible role in the increase of the host capacity of RES. The installation of ESS could help to overcome the main drawbacks of RES (i.e. intermittency and uncertainty), by increasing the share of self-consumption and improving the reliability of electricity distribution systems. Nevertheless, the economic feasibility of the installation of ESS is still uncertain, because the revenues coming from the increase of self-consumption are usually not sufficient to cover the investment costs. This work presents a detailed analysis of the electricity tariffs reform impact on DG and ESS for non household customers under different conditions.

Keywords: Electricity tariffs; Distributed generation; Renewable energy sources; Energy storage; Life cycle cost.

1. Introduction

In Italy, electricity tariffs are differentiated by type of user, and almost all the tariff components are defined through a trinomial structure. The only exception is represented by the system costs component, which presents substantially a one-part structure (i.e. a variable share function of the amount of electricity purchased from the grid). System costs are intended to cover the costs related to activities of general interest for the electricity system. In past years, the already high electricity prices have further increased for non household customers. This is mainly due to growing costs required to support renewables development, to cover grid charges, as well as to finance additional measures to promote energy efficiency (Deloitte Conseil, 2015).

System costs are defined by several contributions and only few components have a binomial structure (fixed rate per point of delivery and variable rate per kWh consumed). However, even for these components, the variable share is the predominant one. In 2015 the Italian legislative decree 210/2015 deliberated that the AEEGSI must re-determine the structure of the tariff components related to the system costs applied to non household customers by January 2018. The aim was to: (i) promote the spread of efficient energy consumption practices, today penalized by excessive investment costs and unattractive electricity tariffs, (ii) simplify the electricity bill and to make it more readable, (iii) make the system costs fairer and more adherent to the actual dispatching costs, and (iv) reduce the dependence of these costs from the energy demand.

As described in the consultation document proposed by the AEEGSI (i.e. 255/2016/R/EEL), the effects of the different options lead to several consequences for users, and the evaluation of those consequences depends on the individual user behavior in the energy purchasing. An instantaneous variation of the system costs from the current structure to the trinomial one may also have undesirable effects, especially regarding investment decisions for the development of renewable energy or to improve energy efficiency for end users. In this perspective, the reform could also affect the diffusion of Energy Storage Systems (ESS) in support of Distributed Generation (DG) based on Renewable Energy Sources (RES). The recent interest on ESS from both the energy market and the research community produced several research streams. Remarkable works focused on the economic evaluation of ESS: (Zakeri and Syri, 2015) presented a comparative life cycle cost analysis among the different electrical energy storage system technologies; (Obi *et al.*, 2017) proposed a methodology for calculating the Levelized Cost of

Electricity (LCOE) for utility-scale storage systems; (Marchi, Pasetti and Zanoni, 2017) investigated the life cycle cost of three different Battery ESS (BESS) technologies, considering investment, operation, maintenance, and disposal costs; (Berrada and Loudiyi, 2016) proposed non-linear programming optimization models for the sizing of a renewable farm equipped with solar and wind power plants; (Bortolini, Gamberi and Graziani, 2014) and (Zanoni and Marchi, 2014) evaluated the sizing and management strategies to minimize the overall system costs of BESS installations for Photovoltaic (PV) applications; (Harsha and Dahleh, 2015) addressed the optimal energy storage management and sizing problem taking into account dynamic pricing of the electricity from the grid; (Marchi, Zanoni and Pasetti, 2016) proposd a techno-economic analysis of lithium-ion batteries supporting distributed generation from PV systems. The main result that can be evinced from the literaure is that the installation of ESS could help to overcome, or at least mitigate, the main drawbacks of RES (i.e. intermittency, non-programmability and uncertainty), that generate relevant problems to the management of distribution grids and hinder the complete replacement of traditional fossil fuels. Moreover, the presence of storage devices could allow the implementation of advanced grid services, such as Virtual Power Plant (VPP) control (Rinaldi *et al.*, 2016), power support functions (Dedé *et al.*, 2016) and demand response capabilities (Fera *et al.*, 2016). The implementation of the aforementioned services would then allow additional revenues and savings, that could contrast the reduction or absence of feed in tariffs for RES and lead to a reduced payback of the investment. Nevertheless, the economic feasibility of the installation of ESS is still uncertain, because the revenues coming from the increase of self-consumption are usually not sufficient to cover the investment costs.

Since the benefits introduced and the return of the investments are strictly dependent on the specific electricity price considered, the aim of the present work is to assess the impact of the tariffs reform on DG and ESS in the case of non household customers, considering the different proposed hypotheses.

The remainder of the article is organized as follows: Section 2 gives an overview of the Italian reform of the electricity tariffs and Section 3 defines the assumptions and the objectives of the analysis. In Section 4, the models and methods are described while in Section 5 a numerical example to illustrate the possible effect of the reform in case of RES coupled with a EES is presented. Finally, Section 6 summarizes the main findings of the present work and provides suggestions for future research

2. The Italian reform of the electricity tariffs

A portion of the components of the Italian electricity bill are under the direct control of the retailer, while others are quarterly defined by the regulatory authority for electricity, gas and water (namely "AEEGSI"), depending on market trends and expectations for the upcoming months. In the first trimester of 2017, the latter component represented 60% of the total bill for an non household customer with Medium Voltage supply.

To meet the requirements established by the decree, the Italian authority has introduced a procedure for the determination of an equivalent trinomial tariff for the different types of non household customers. Currently, three different hypotheses are under investigation and all of them propose a structure made up of a fixed part per Point Of Delivery (POD) and of two variable components, defined respectively as a function of the rated power demand and of the energy demand.

2.1. The current tariff structure

The Italian electricity bill is made up of four cost components: costs related to the energy procurement, grid costs (i.e. metering, distribution and transmission), system costs and taxes. The system costs applied to non household customers cover costs related to different activities, such as: dismantling of decommissioned nuclear power plants (component A2), incentives for renewable sources (A3), application of special tariff conditions (A4), research and development (A5), adoption of measures to preserve tariffs of customers in a state of discomfort (AS), concessions for companies with a strong electricity consumption (AE), tariff subsidies for power companies operating in the smaller islands (UC4), promotion of energy efficiency practices among end users of electricity (UC7) and territorial compensation to local governments that host nuclear plants (MCT). The general expression of the cost of electricity, excluding taxes, is represented by eq. 1:

$$c_{\mathrm{e}} = c_{\mathrm{p}} + c_{\mathrm{g}} + c_{\mathrm{s}} \tag{1}$$

where c_{p} is the cost related to the energy procurement, c_{g} is the grid cost and c_{s} is the system cost. The current Italian electricity tariff is generally defined by a trinomial structure, with: (i) a fixed component per POD, defined as α, (ii) a variable component function of the maximum power taken from the grid (measured on monthly basis), defined as β, and (iii) a variable component function of the energy purchased from the grid, defined as γ. Even though not all the tariff costs are defined by means of a trinomial structure, all of them can be expressed referring to the α, β and γ coefficients. In the following the specific structure of each tariff cost is defined in detail. The cost for the energy procurement is function only of the purchased energy, as defined by eq. 2.

$$c_{\mathrm{p}} = \gamma_{\mathrm{p}} E_{\mathrm{FU}} \tag{2}$$

The grid cost has specific parameters for metering, distribution and transmission, as defined by eq. 3:

$$c_{\mathrm{g}} = \alpha_{\mathrm{d}} + \alpha_{\mathrm{m}} + \beta_{\mathrm{d}} P_{\mathrm{FU,max}} + (\gamma_{\mathrm{d}} + \gamma_{\mathrm{tr}}) E_{\mathrm{FU}} \tag{3}$$

The system cost is computed as function of the fixed component α and of the variable component γ, as defined in eq. 4:

$$c_{\mathrm{s}} = \alpha_{\mathrm{s}} + \gamma_{\mathrm{s}} E_{\mathrm{FU}} \tag{4}$$

2.2. Proposed modification of the system costs

The decree states that the structure of the system costs should be adherent to the structure of the grid costs, thus all the different hypotheses proposed by the AEEGSI present a trinomial structure, as defined in eq. 5

$$c_s' = \alpha_s' + \beta_s' P_{\mathrm{FU,max}} + \gamma_s' E_{\mathrm{FU}} \quad (5)$$

where α_s', β_s' and γ_s' are defined for each hypothetic tariff proposed by the AEEGSI.

Three different hypotheses have been proposed by the AEEGSI and are currently under investigation:

- The first hypothesis (H.A) defines a structure fully reflective of the grid costs.
- A second hypothesis (H.B) considers a structure in part reflective of the grid cost and in part obtained through a linear combination between H.A and a charge for the energy purchased from the grid. In particular, three different weights are currently analysed so three different scenarios can be defined (H.B1, H.B2 and H.B3).
- The last hypothesis (H.C) presents a differentiated structure for the financing of renewable energy and other charges.

3. Assumptions and objectives of the analysis

The objective of the proposed analysis is to assess the impact of the tariffs reform on DG and ESS in the case non household users characterized by the same yearly energy consumption, and by different load profiles.

In the present analysis, we considered three different user's profiles: an industrial user working on three shifts (User 1), an industrial user working on one shift (User 2), and a large hospitality operator (User 3). All the users are characterized by the same yearly energy consumption (1 GWh/year) and by different load profiles, with a peak power demand ranging between 120 kWp (User 1) and 230 kWp (User 3). Detailed information about the user's load profiles considered in the present analysis are given in section 4.1. For each user, we considered the presence of a PV power plant with two different configurations, with an expected yearly energy production of, respectively, the 30% and the 60% of the yearly user's load consumption. The modelling of the PV power plant is discussed in section 4.2. Finally, for each combination of user and PV configuration, we assumed the installation of a Lithium-Ion Battery Energy Storage System (Li-Ion BESS), with a gross capacity capable to store the average daily excess of energy produced by the PV system (computed on yearly basis). Information about the modelling of the BESS is reported in section 4.3. For each scenario, the energy balances within the users and the distribution grid have been computed with a simulation time step of 15 minutes over a time horizon through a custom C++ code. The computed energy flows have been then used to compute the system costs for the current tariff structure and under the different hypotheses proposed by the tariff reform. To better observe the variation of the system costs introduced by the tariff reform hypotheses, the acquisition costs of PV and BESS systems haven't been considered, thus focusing only on currently operating systems.

4. Models and methods

In the following, the models and methods used in the present analysis are described and discussed.

4.1. User's power demand profiles

Each user's profile was defined considering the typical daily power demand profile of the user's loads. Each user's load profile was then computed over a time horizon of 1 year with a time resolution of 15 minutes, taking into account the working days, the non-working days and holidays, according to the specific working schedules In particular, during non-working days and holidays, the expected power demand was set to the 25% of the working day peak power. The expected load's energy consumption during one year for each i-th user, $\overline{\mathrm{E}}_{\mathrm{L,Y,i}}$, was then computed.

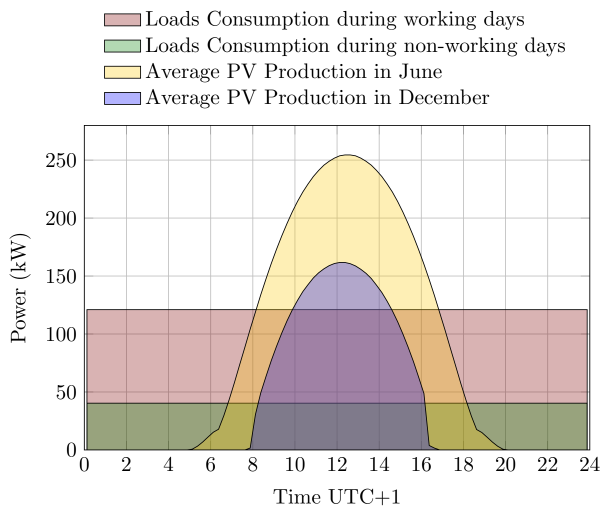

Figure 1: Typical power demand profiles of user 1, and expected PV production in the case of 60% of PV share., corresponding to a nominal power of 414 kWp.

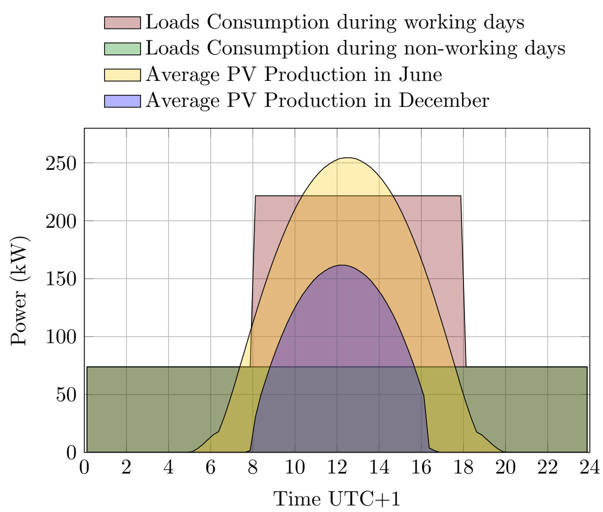

Figure 2: Typical power demand profiles of user 2, and expected PV production in the case of 60% of PV share, corresponding to a nominal power of 414 kWp.

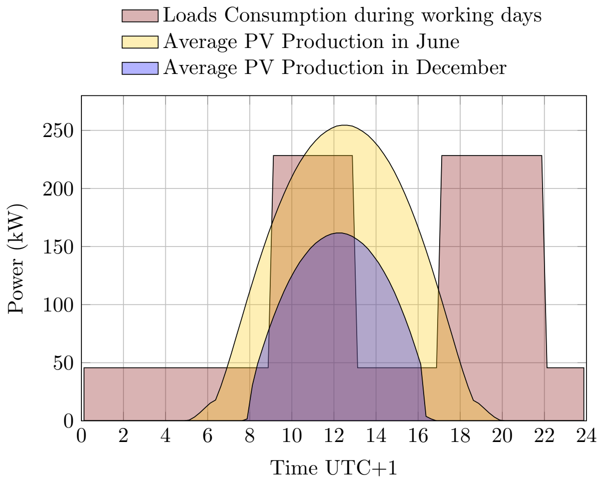

Figure 3: Typical power demand profiles of user 3, and expected PV production in the case of 60% of PV share, corresponding to a nominal power of 414 kWp.

The typical daily power demand profiles of users, along with the expected PV power generation profiles in the case of 60% of PV share, are depicted in Figure 1, Figure 2, and Figure 3, respectively for user 1, user 2, and user 3.

4.2. PV model

In the present analysis, we considered a PV power plant located in Rome (chosen as reference site because of its central location in the Italian territory) based on crystalline silicon technology, which is the most used technology for the PV plants currently installed in Italy. We assumed a fixed PV system with an orientation of 0 degrees South and an optimal inclination of the PV field. The optimal tilt and orientation angle of the PV field was computed by the Photovoltaic Geographical Information System (PVGIS) of the Joint Research Centre of the European Community (European Commission, Joint Research Centre). The maximum nominal power of the PV plant for each i-th user, $P_{\text{PV,max},i}$, was computed by applying the typical dimensioning rule for grid-tied PV plants accessing the net metering scheme, as defined in eq. 6:

$$P_{\text{PV,max},i} = \frac{\bar{E}_{\text{L,Y},i}}{\bar{E}_{\text{ref,PV}}} \tag{6}$$

where $\bar{E}_{\text{ref,PV}}$ is the yearly PV reference yield, that is the expected yearly energy production of a PV plant with a nominal power of 1 kWp. The value of $\bar{E}_{\text{ref,PV}}$ was computed by applying the model described in (Huld *et al.*, 2010) to the typical daily irradiance and ambient temperature profiles of the given location (defined every 15 minutes, for each month) provided by the PVGIS.

For the calculation of the PV output power, we assumed a combined system loss of 16% (including both system losses and aging effects), and applied the DC/AC conversion efficiency curve depicted in Figure 4. The nominal power of the PV plant for each scenario was then computed by means of the following equation:

$$P_{\text{PV},i} = \delta P_{\text{PV,max},i} \tag{7}$$

where δ is a parameter that defines the ratio between the expected yearly energy production of the PV plant and the yearly energy consumption of the user's loads.

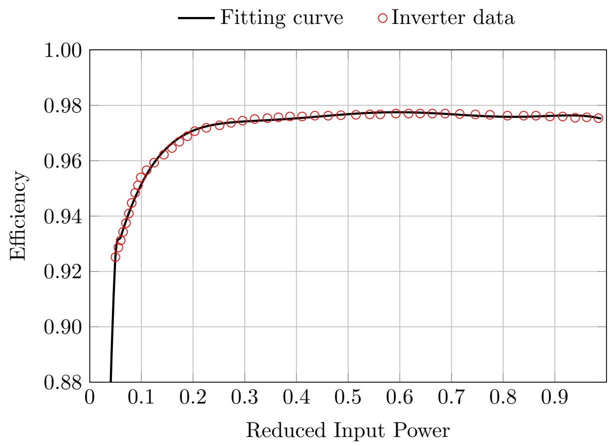

Figure 4: Efficiency curve of the power conversion systems considered in the present analysis.

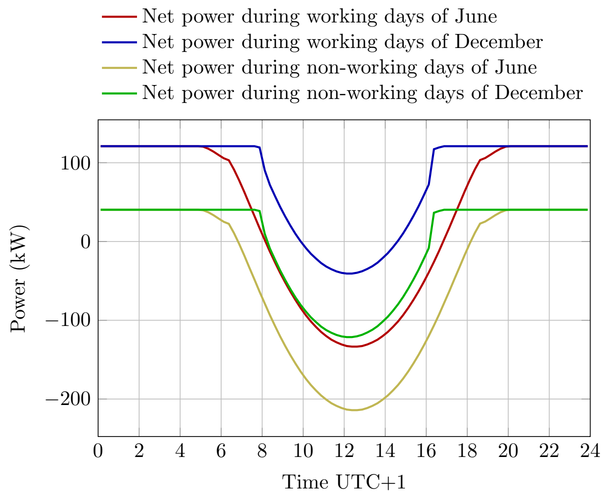

Figure 5: Typical net power profiles of user 1 with a PV share of 60%. Positive values represent power taken from the grid.

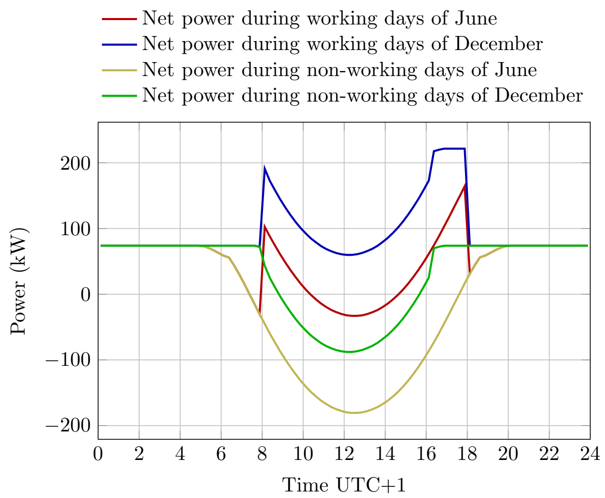

Figure 6: Typical net power profiles of user 2 with a PV share of 60%. Positive values represent power taken from the grid.

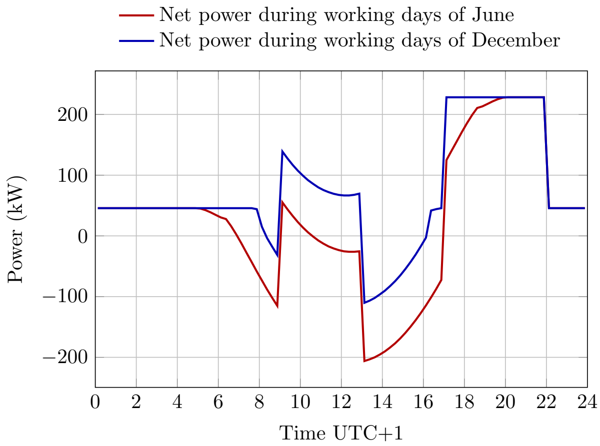

Figure 7: Typical net power profiles of user 3 with a PV share of 60%. Positive values represent power taken from the grid.

For each use case (i.e. for each user, with the two different PV share hypotheses), the energy balance with the distribution grid was computed taking into account the load power demand and the PV power generation profiles. The typical net power profiles for the considered users are depicted in Figure 5, Figure 6, Figure 7, respectively for user 1, user 2, and user 3.

4.3. BESS model

The model used to compute the energy performance of the BESS is described in (Marchi, Zanoni and Pasetti, 2016). With respect to the model parameters reported in (Marchi, Zanoni and Pasetti, 2016), in the present analysis the nominal power of the BESS was computed as the minimum value between the maximum power allowed by the whole battery pack and the maximum value of the power fed to the utility grid by the system. The efficiency of the BESS power conversion system was computed by means of the conversion efficiency curve depicted in Figure 4.

For each use case, the energy balance with the distribution grid was computed taking into account the load power demand profiles, the PV power generation and the charge and discharge power flows of the storage system. The typical net power profiles for the considered users are depicted in Figure 8, Figure 9, Figure 10, respectively for user 1, user 2, and user 3.

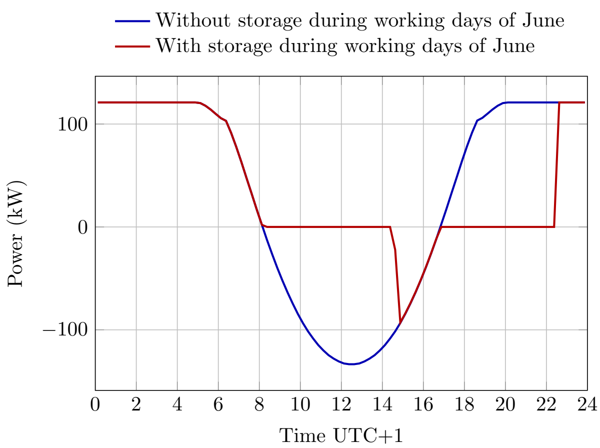

Figure 8: Typical net power profiles of user 1 in the case of 60% of PV share with a 650 kWh and 230 kWp Li-Ion BESS.

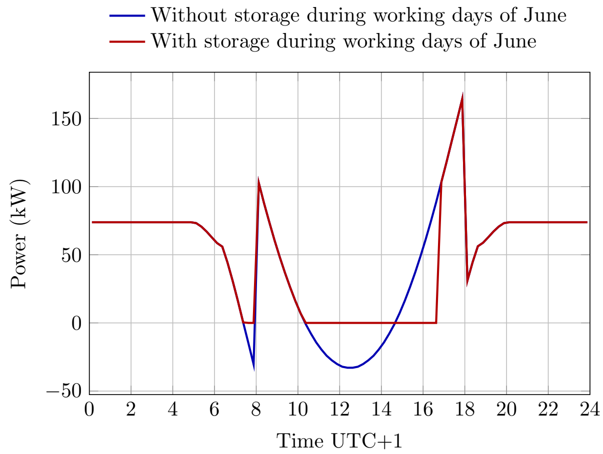

Figure 9: Typical net power profiles of user 2 in the case of 60% of PV share with a 388 kWh and 198 kWp Li-Ion BESS.

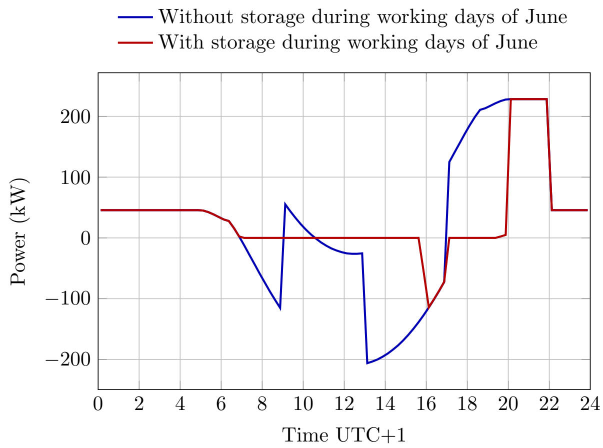

Figure 10: Typical net power profiles of user 3 in the case of 60% of PV share with a 629 kWh and 223 kWp Li-Ion BESS.

5. Results and discussion

The system costs for the considered use cases with the current tariff structure are shown in Figure 11. The current structure promotes users with larger PV share, especially if equipped with a BESS. This is mainly due to the reduced grid consumption for users with a PV plant and storage systems, especially for those users who can benefit from high self-consumption indices. In fact, user 2 with 60% of PV share shows the lowest system costs among the configurations without BESS, thanks to the good match between the load demand and the PV generation profiles. It is worth to note that for low PV shares, the use of storages system does not significantly affect the systems costs. This result can be explained by the high self-consumptions indices of the PV configurations, that result from the low power output of the PV system, if compared to the relative high power demand of the loads. On the contrary, for high PV shares, the effect of the presence of storage systems is apparent. In this case, for all the considered users, the power output of the PV plant is often higher than the power demand. As a consequence, the opportunity to store and lately reuse the excess of energy generated by the PV leads to lower yearly grid consumption, and thus to lower system costs.

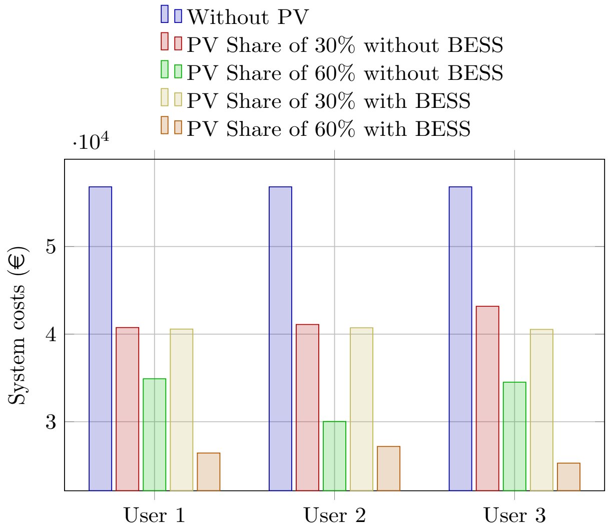

Figure 11: Yearly system costs for all the considered use cases, computed with the current system costs structure.

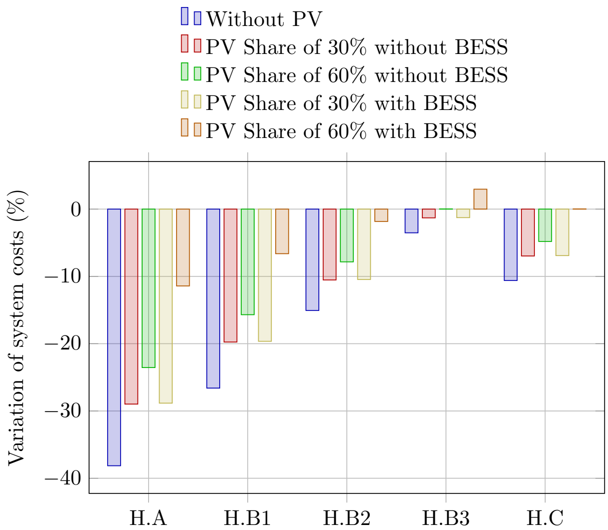

Figure 12: Percentage variation of yearly system costs for user 1, computed against the current system costs.

Table 1: System costs for the different scenarios and different users under hypothesis H.A. Values are reported in k€/year.

Scenario	User 1	User 2	User 3
Without PV	35.145	44.124	44.726
PV Share of 30% no BESS	28.944	37.047	39.461
PV Share of 30% with BESS	28.877	36.902	38.443
PV Share of 60% no BESS	26.687	31.762	36.116
PV Share of 60% with BESS	23.415	30.662	32.549

The variation of the system costs for the considered use cases are shown in Figure 12, Figure 13, and Figure 14, respectively for user 1, user 2, and user 3. The figures show the percentage variation of the yearly system costs, computed against the current costs, for all the hypotheses proposed by the tariff reform.

The results of the analysis show that for all the considered users without PV and BESS, almost every hypothesis leads to reduced yearly system costs, with the sole exception of hypothesis H.B3 for users 2 and 3, which leads to higher system costs also for users without a DG system.

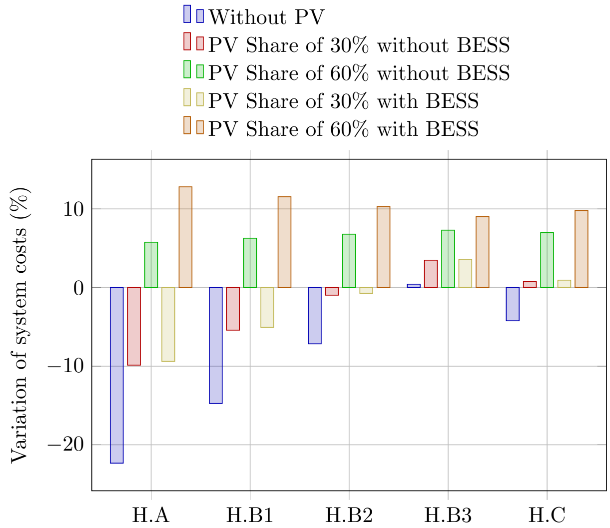

Figure 13: Percentage variation of yearly system costs for user 2, computed against the current system costs.

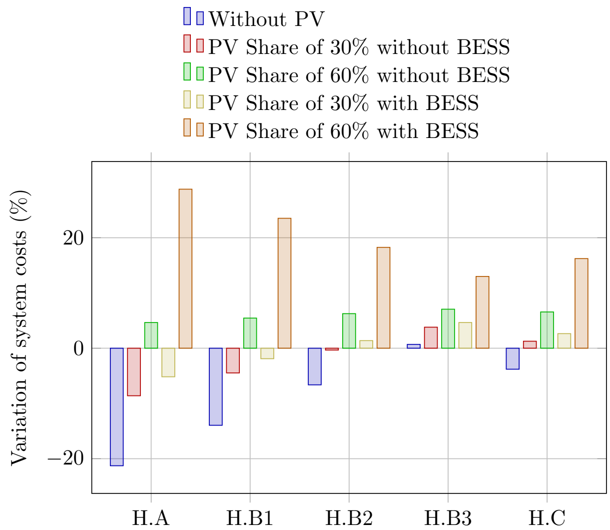

Figure 14: Percentage variation of yearly system costs for user 3, computed against the current system costs.

On the contrary, almost every user equipped with PV and BESS shows increased system costs, with the sole exception of user 1, and users 2 and 3 in case of low PV share (both with and without BESS) for hypotheses H.A, H.B1 and H.B2. This is mainly due to the higher weight that the cost component related to the energy taken from the grid has with respect to the other components.

Shifting from the AS-IS scenario to the new hypotheses, the bigger the PV plant the lower is the reduction of the system costs. In some cases, the variation is even positive: i.e. the system costs obtained with the reform tariff structure are higher than the one of the old scenario. Moreover, the results are strictly dependent of the type of user. In fact, if users characterized by greater grid energy consumption (i.e. with constant load power demand profiles, or without DG systems) would generally expect a decrease of system costs, users with a better match between the load power demand and the PV generation profiles would face lower variations with respect to users with a poor match between GD and power demand.

Finally, it is worth to note that for all the considered scenarios, the proposed tariff reform seems to not reward the installation of ESS, even if, in some of the considered use cases, the introduction of such systems demonstrated positive effects on the energy balance of users with large PV installation. This is the case, for instance, of users 3, where the installation of the storage system demonstrated the ability to effectively reduce the power flows perturbation within the grid generated by the combination of PV generation and loads consumption (see Figure 10).

6. Conclusions

In this paper, we investigated the effect of the Italian reform of electricity tariffs for non household customers (Legislative Decree No. 244/16) on DG and ESS. The variation of system costs was analyzed for three users characterized by the same yearly energy consumption (1 GWh/year) and by different load profiles, considering the presence of a PV system and of a lithium-ion BESS. The results of the numerical analysis revealed that, for all the considered use cases without DG and ESS, all the reform hypothesis would lead to lower system costs. On the other hand, the effect in case of current operating DG systems and EES is questionable. Even if the presence of PV and ESS always allows the reduction of systems costs, the variations that would be introduced by the reform are variable. Generally, the bigger the current PV plant, the lower is the percentage reduction of the system costs. In some cases, the variation is even positive (i.e. leading to higher costs). This effect seems also to be particularly apparent for BESS. However, it should be noted that if the perspective is on new system installations, the bigger the new PV plant, the higher will be the reduction of the system costs, with EES unveiling their positive effect when the PV system covers a consistent part of the consumption.

Further investigation may look at different user's load profiles (e.g. mainly considering those customers that will experience system costs increase under the hypothesis of the reform with respect to the current structure, such as customers with lumpy or with severe peak electricity demand), different configuration or categories of DG systems and to different dispatching rules for the EES (e.g. looking at mainly peak shaving purposes).

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