THE ROLE OF MARKET FACILITATOR - HOW DSO-OWNED ENERGY STORAGE SYSTEMS CAN SUPPORT PRIVATE RESOURCES IN ANCILLARY SERVICES MARKET

Daniele CLERICI	Marco ROSSI	Giacomo VIGANÒ	Diana MONETA
Ricerca sul Sistema Energetico – Italy	Ricerca sul Sistema Energetico – Italy	Ricerca sul Sistema Energetico – Italy	Ricerca sul Sistema Energetico – Italy
daniele.clerici@rse-web.it	marco.rossi@rse-web.it	giacomo.vigano@rse-web.it	diana.moneta@rse-web.it

ABSTRACT

The paper deals with the issue of using assets for supporting network operations, without being in conflict with business actors. It is presented a novel business framework in which the distribution system operator, playing the role of market facilitator, operates its own energy assets (including energy storage) in a pro-active way, using them to support the distribution resources in participating to the ancillary services markets.

INTRODUCTION

The decarbonisation of energy systems goals set by policy makers encouraged a steady increase of the penetration of renewables in the electricity networks which, in some cases, has reached peaks of more than 50% of generation mix. At the same time, also the presence of private-owned flexible energy resources in distribution networks is growing.
The changeover from a high share of conventional power plants to a high share of non-programmable energy sources arise the need of different approaches for network management.
Specifically, new rules and solutions are needed for ancillary services provision, in order to keep high levels of reliability and resilience expected from electricity networks. Novel network operation schemes, as well as installation and exploitation of new kind of assets and management systems, are studied, tested and deployed more and more within research projects and physical pilots [1][2].
In such a scenario, the distribution system operators are facing new challenges in the way they manage their networks: the evolution of business frameworks aimed to allow private plants connected to distribution networks to participate to the electricity energy and ancillary services markets, may request that distribution system operators assume new business roles, in addition to network operator. Alternative scenarios in which the Distribution System Operator (DSO) plays the role of market operator (managing a local flexibilities market) are under study [1][2].
These evolutions are extremely challenging for the distribution networks, since they are not designed to deal with large variations of resources consumption and/or generation due to system flexibility needs, so suitable measures should be applied.
Presently, the improvements in distributions networks aimed to accommodate more energy resources (and dealing with flexible and highly variable power flows) follow two directions: network reinforcement and smart solutions application.
Design of new lines and reinforcement of existing ones are the most common solutions adopted by DSOs in case of systematic violations of network constraints. Furthermore, reinforcement may have a consistent impact on network operations, so it requires an accurate planning on the long-term. This aspect may spoil its effectiveness, particularly for congestion which happens randomly, not frequently and, in general, within the short-term horizon.
A wide range of smart solutions has been studied and deployed during the last years, e.g. the modulation of reactive power exchanged by distributed generators. Smart solutions include also new type of assets as, for example, Battery Energy Storage Systems (BESS) [3][4]. Several studies about BESS exploitation in distribution networks have been carried out, focusing both on innovative business models for network services provision [5][6] and test pilots activities [7]-[9].
However, BESS application and deployment in large scale, by system operators, is often not feasible due to several factors: besides cost and technical issues, the regulatory constraints represent a major step for the implementation of such improvements [10][11]. An exception to this rule can be realized if BESS are exploited for supporting network operations, without being in conflict with other business actors: this topic is highly debated at present [12][13].
These two apparently conflicting scenarios can be managed in a novel business framework in which the distribution system operator, playing the role of *market facilitator*, operates its own energy assets in a pro-active way, using them to support the private flexible resources in participating to the ancillary services markets. The paper proposes a promising business use case for the exploitation of optimal network and storage systems management, aimed at maximizing the participation of local flexible resources to vertically integrated ancillary services.

THE PROPOSED BUSINESS CASE

In accordance with the evolving scenario described in the previous section, in the near future DSOs may be called to play the market facilitator role in order to guarantee the participation of distributed resources to the energy and the ancillary services markets.

The fulfilment of this role requires that DSOs mitigate or remove all the potential hindering factors, related to distribution network operations/planning, which can lead to partial/total curtailment of the energy bids offered by distributed resources to the centralized markets. In particular, local network congestions can be considered the main threat for trading (flexible) energy by distributed resources.

A possible alternative solution to network reinforcement could be achievable through the usage of BESS, managed by DSOs, focused on supporting the role of neutral market facilitator.

This approach is based on the "virtual line" concept: whenever the DSO is forced to curtail a power plant for network operation purposes (i.e. to avoid congestions), it can "restore" the energy not produced by the plant by means of energy injection from the BESS connected to the primary substation (or to a non-congested network feeder). Furthermore, the BESS exploitation allows the DSO to solve/avoid imbalances due to local congestion management. For example, if DSO uses a portion of an active power flexibility, provided by a local generator, it can be able to re-inject the corresponding energy through the storage unit; the same if the DSO exploits a consumption flexibility offered by a load.

From an economic point of view, the remuneration of storage operation should be included in operational expenditures, and not based on the amount of energy injected; suitable hypotheses should be considered in order to compensate the cost of the energy losses afforded by the DSO. Furthermore, in case the DSO activates flexibility for distribution network management purposes, the same flexibility (which was part, for instance, of a frequency regulation reserve) is provided by the BESS to the transmission network. In this last case, the corresponding remuneration could be managed in two ways:

1. the DSO pays the flexibility to the resource and receive a remuneration from the centralized market (this solution requires a suitable regulation for the transparency of the transactions, in order to avoid potential speculation: the expenditure for the flexibility in distribution network should be equivalent to the remuneration from the centralized market);
2. the flexibility provision is remunerated directly from the centralized market to the distributed resource, as it would happen if the distribution network is not constrained and/or the DSO does not exploit the flexibility for its own purposes (in these conditions, a suitable metering service should be installed and managed neutrally, i.e. by a third party).

The proposed approach has two major challenges, which need attention:

1. Storage system dimensioning: it is highly influenced by the features and performances of the network, the frequency of occurrence of congestions due to flexibility provision by local resources, the average energy size of flexibility offers, the congestions occurrence, the critical branches and nodes, etc.
2. Storage integral constraint: this poses a limit on the actual capability of the storage to support the tasks explained before. Indeed, the rebalancing operations should be performed in both directions (charging/discharging) or, in general, a suitable charge/discharge scheduling should be followed.

These aspects should be necessarily taken into account for field operations. Anyway, the aim of this paper is to show, through dedicated simulations, the soundness of this novel application of BESS for network operations. Further analysis of the implications of actual field use will be carried out in depth in future work.

CONSIDERED SCENARIO

The service and operation of BESS can be beneficial in several distribution network scenarios. Having assumed the role of market facilitator for the DSO, network operations are aimed at managing the available assets in order to transfer (without distortions/limitations) the flexibility of distribution resources to the ancillary services markets. In this background, BESS has the potential of being a valuable network asset and the following scenario is hypothesized in order to show practical situations in which the DSO takes advantage of storage flexibility to allow the participation of all the resources to the market.

Distribution network characteristics

Typically, rural distribution networks are the most challenging systems to be managed. In particular, distributed generation is expected to significantly increase in rural areas, far from the primary substation. This situation normally drives to voltage issues which can be often solved by acting on the reactive power modulation of distribution resources. However, overloading issues can also occur, determining the necessity of curtailing/limiting the upward/downward flexibility of resources in terms of active power.

One network in which both voltage and loading issues can be experience is represented by the one reported in Figure 1. It consists of a typical Italian rural distribution network [14] which is mainly characterized by a domestic demand (uniformly distributed on the grid) and includes Photovoltaic (PV) and Hydroelectric (Hydro) generation plants. The total generation/consumption curves are plotted in Figure 1.

Detailed description of the resources

For the illustrated system, the source of flexibility is represented by the generation power plants. Renewable generation is supposed to provide mainly downward regulation flexibility, which can be operated by simply curtailing the production (from the baseline power to

zero). In addition, the availability of upward reserve is hypothesized, making the simulated power plants capable of increasing the production by 20% when requested.
The cost of providing flexibility can be largely affected by the generation technology and the bidding strategy adopted by the aggregators. Since the document is not focused on the evaluation of this aspect, the following simple assumptions are taken:

- Most of the Hydro and some PV units are bidding at +30 €/MWh and +10 €/MWh upward and downward regulation respectively;
- The remaining power plants are bidding at +50 €/MWh and +20 €/MWh upward and downward regulation respectively.

According to these assumptions, the merged flexibility of the simulated resources results in the ideal bidding curves reported in Figure 2.

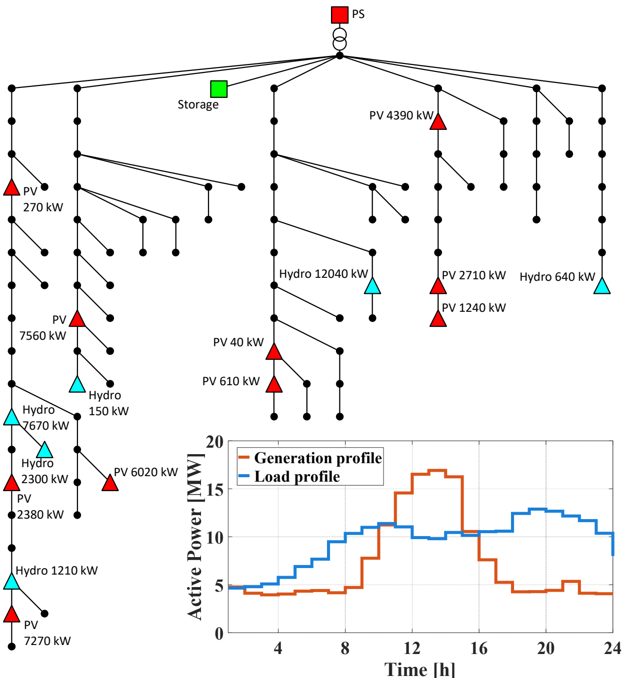

Figure 1. Simulated 20 kV distribution network of a typical Italian rural system and profiles of the total generated/absorbed active power.

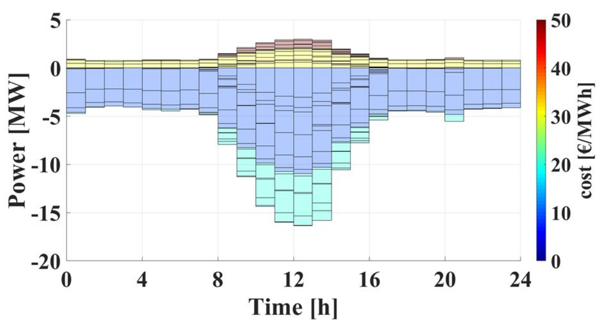

Figure 2. Available flexibility of generation power plants for each simulated time step (ideal flexibility curve). The flexibility is calculated as deviation from the baseline profile.

In order to accomplish its role of market facilitator, the DSO has to guarantee that this flexibility is fully exploitable by the ancillary services market. For this reason, any network bottleneck preventing the activation of the controlled resources must be managed by opportunely acting on the network assets.

SIMULATION RESULTS

The network described in the previous section have been simulated in order to evaluate the impact of its energy transfer capacity on the flexibility bids proposed by the energy resources. As anticipated above, the selected network is featuring a large presence of distributed generation and its rural characteristics are frequently determining overvoltage and overloading issues.
For this reason, ancillary services markets cannot always count on the full availability of the submitted bids. In fact, as it can be noticed in Figure 3, network constraints are limiting the activation of a relevant portion of regulation reserve, especially in correspondence of the peak production of photovoltaics.

Exploitation of reactive power for voltage issues

One of the main limitations of rural distribution networks is represented by voltage congestions occurring in the most remote areas of the grid. High electrical distances determine relevant voltage sensitivities to power generation and, often, they can be effectively mitigated by acting on the reactive power of the interested units.
Having assumed that the central distribution management systems can remotely control the reactive power of the generators, voltage can be optimally managed, and the available flexibility can be further increased (as reported in Figure 4).

Exploitation of BESS

Even if the reactive power modulation is an effective measure for the improvement of the bidding curve, some resources are still inhibited by network loading constraints. In this situation, not all the flexibility requests can be fully actuated but, according to the business case described above, the BESS can substitute the blocked units in providing the demanded activation.
Having assumed a proper storage power and capacity, the blocked resources can be "virtually" activated, bringing the limited flexibility curve to the ideal one (as reported in Figure 5).
The benefits achieved thanks to the management of reactive power and operation of storage device can be analysed also looking at the most critical time frame (12:00 – 13:00). By comparing the resulting bidding curves (Figure 6), it is particularly noticeable how the combination of the selected strategies can restore the ideal bidding curve, virtually eliminating the network bottlenecks in sharing flexibility.

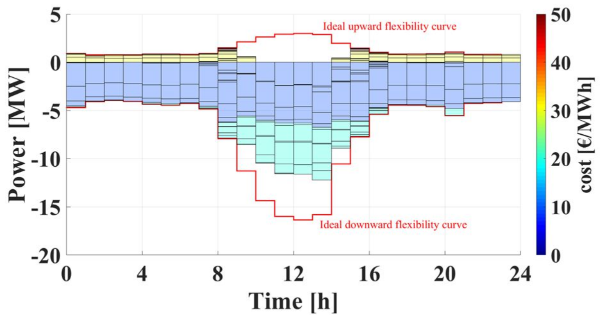

Figure 3. Available flexibility of generation power plants for each simulated time step, having considered distribution network constraints (the flexibility that causes network limits violation is removed from the resulting curves).

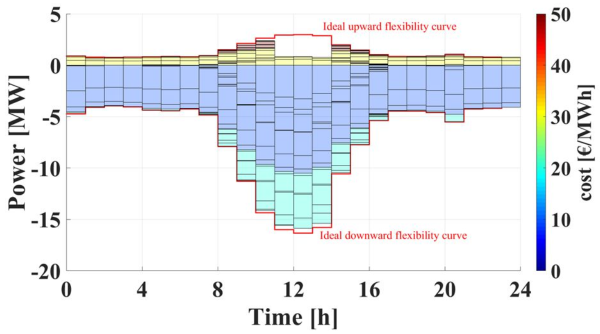

Figure 4. Available flexibility of generation power plants for each simulated time step, having considered distribution network constraints and optimal control of reactive power (aimed at solving voltage issues).

STORAGE DEVICE OPERATION

As anticipated above, despite the apparent potential of the BESS in supporting the DSO role of market facilitator, the practical operation of a storage unit determines a series of technical issues that have to be faced since the design phase.

Storage device dimensioning

The simulations results reported in the previous section represent a fundamental step for the BESS dimensioning, and the most critical operating conditions can be taken as design reference.

Having assumed that the entire upward flexibility is requested by the ancillary services market, reactive power modulation and BESS have to be optimally operated in order to guarantee the provision of the requested active power increase. Figure 7 and Figure 8 reports the power profiles of generators and storage unit returned by the simulator in this extreme situation.

In particular, it can be noticed that the power that cannot be provided by the flexible generation is injected by the BESS. As detailed above, even if not physically activated, the remuneration of this upward service is directly/indirectly forwarded to the inhibited flexible resources. The same procedure can be repeated for a hypothetical activation of the entire downward flexibility.

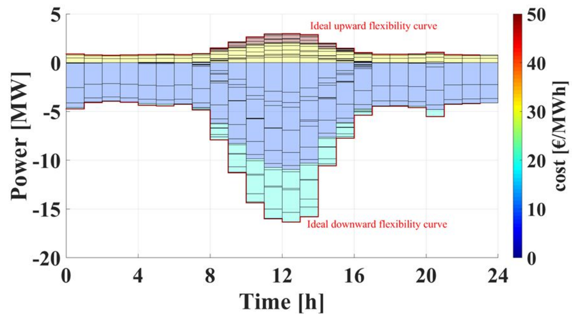

Figure 5. Available "virtual" flexibility of generation power plants for each simulated time step, having considered distribution network constraints, optimal control of reactive power (aimed at solving voltage issues) and BESS operation.

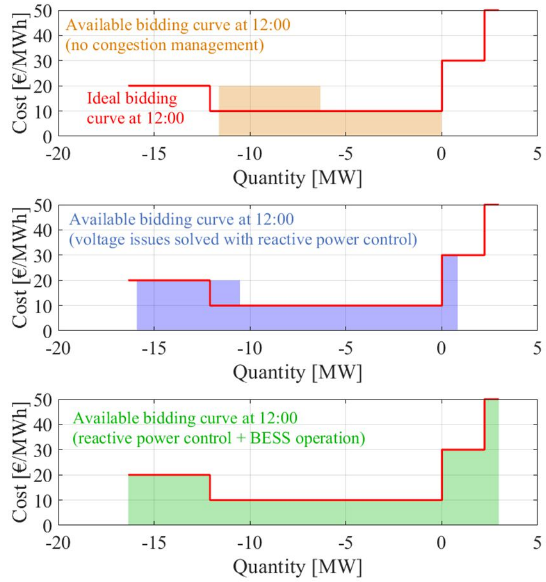

Figure 6. Global bidding curves (calculated for the time interval 12:00-13:00) achievable in the three analysed situations and compared with the ideal one.

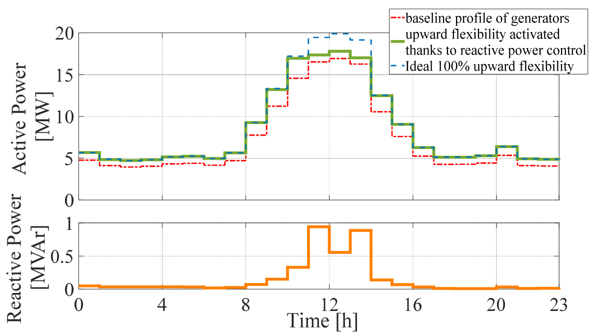

Figure 7. Active and reactive power exchanged by distributed generation when 100% of upward regulation is requested.

Having analysed the simulated profiles (Figure 8), it is immediate to realize that the BESS can perform the requested functions when its rated power exceeds 2.2 MVA and for storage capacities up to 7 MWh (which are the maximum power and total energy requested in the

simulated scenario respectively). Of course, more complex and exhaustive scenarios (with a more statistically meaningful set of situations) have to be considered for a more precise BESS dimensioning.
This dimensioning can also consider reactive power flexibility. In fact, BESS can be used also for power factor compensation and "absorbs" the reactive power of activated distributed generators and loads (Figure 8).

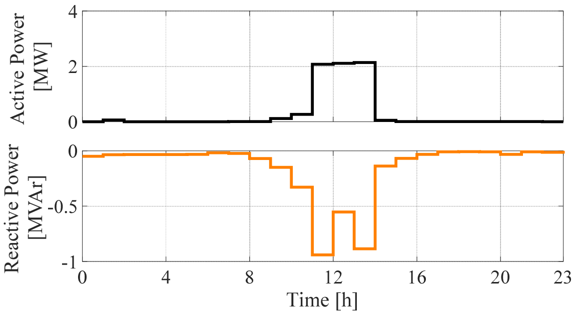

Figure 8. Active and reactive power exchanged by the BESS when 100% of upward regulation is requested.

Restoration of the state-of-charge

One of the main practical problems of the investigated business case is related to the restoration of the state of charge of the BESS. In fact, in order to provide the requested flexibility, storage capacity and stored energy have to be promptly available and periodically restored.
According to that, dedicated use cases should be opportunely investigated, taking always into account the regulatory and economic risks behind the operation of BESS owned by the DSO. One possibility, for instance, may consists of activating the flexibility of local resources with the specific purpose of restoring the requested state of charge. Of course, it has to be part of a non-activated reserve and accordingly remunerated.

CONCLUSION

The document details a possible business case addressed to DSOs based on the owning and managing of storage units. Having considered the motivations behind the regulatory frameworks on the issue, the presented work demonstrates how BESS can be operated without interfering with energy and power markets. In fact, the proposed case study highlights that:

- network constraints can be a noticeable limitation in exploiting the entire flexibility reserve from distribution energy resources;
- storage units can be used in order to "virtually" enable the entire distribution reserve in the provision of ancillary services (with no impact on the system balancing).

According to this business case, BESS has the potential of being considered as a conventional grid asset and, assuming further technology improvements, a cost-effective substitute of network refurbishment.

In addition to the economic convenience of BESS, several aspects (e.g. restoration of the state of charge, impact on network losses, etc.) will be further investigated by the authors in order to develop a fully regulatory/technically/economic proof business case.

Acknowledgments

This work has been financed by the Research Fund for the Italian Electrical System under the Contract Agreement between RSE S.p.A. and the Ministry of Economic Development - General Directorate for Nuclear Energy, Renewable Energy and Energy Efficiency in compliance with the Decree of Mar.8, 2006.

REFERENCES

[1] EU-SysFlex Project, http://eu-sysflex.com/
[2] SmartNet Project, http://smartnet-project.eu/
[3] IRENA, 2015, "Battery Storage for Renewables: Market Status and Technology Outlook "
[4] A. Malhotra *et. al.*, 2016, "Use cases for stationary battery technologies: A review of the literature and existing projects", Elsevier *Renewable and Sustainable Energy Reviews* vol.56, 705-721.
[5] A. Castillo, D. F. Gayme, 2016, "Grid-scale energy storage applications in renewable energy integration: A survey", Elsevier *Energy Conversion and Management*, vol.87, 885-894.
[6] K. Mahani, F. Farzan, M. A. Jafari, 2017, "Network-aware approach for energy storage planning and control in the network with high penetration of renewables", Elsevier *Applied Energy*, vol.195.
[7] S.A.R. Mir Mohammadi Kooshknowa, C.B. Davis, 2018, "Business models design space for electricity storage systems: Case study of the Netherlands", Elsevier *Journal of Energy Storage*, vol.20, 590-604.
[8] F. R. S. Sevilla *et. al.*, 2018, "Techno-economic analysis of battery storage and curtailment in a distribution grid with high PV penetration", Elsevier *Journal of Energy Storage*, vol.17, 73-83.
[9] D. Colin *et. al.*, 2015, "The VENTEEA 2 MW/1.3MWh Battery System: an industrial pilot to demonstrate Multi-Service operation of Storage in Distribution Grids", *CIRED 2015*, paper no. 0738
[10] Q. X. Latour *et. al.*,2015, "Electricity Storage: how to enable its deployment?", paper no. 1270, CIRED
[11] F. Tang *et. al.*, 2017, "Business Case for Distributed Energy Storage", *CIRED 2017*, paper no. 0491
[12] G. Pisano, L. Lo Schiavo et.al., "Assessment of Energy Storage Systems Installation in Smart Distribution Networks", paper A2.3, AEIT 2018
[13] CIGRE WG C5.25, 2019, "Regulation and market design barriers preventing to capture all the value from fast and high-locations-freedom energy storage"
[14] F. Pilo *et al.*, 2012, "ATLANTIDE — Digital archive of the Italian electric distribution reference networks," *CIRED 2012*, paper no. 0165