Sizing of Battery Storage Systems to Mimic the Operation of RES-based VPPs in Electricity Markets

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***Abstract*—The presence of large-scale Battery Energy Storage Systems (BESSs) in the grid is increasing at a quick pace, mainly to facilitate the process of the also increasing penetration of Renewable Energy Sources (RESs). However, BESSs are not exempt from caveats and limitations. In this regard, the interest in coordinating already installed resources in the form of RES-only Virtual Power Plant (RVPP) for energy market participation and ancillary services provision is rapidly growing. This paper determines the size of BESS needed to achieve similar economic performance as an RVPP in the energy and ancillary service markets for different levels of uncertainty and weather conditions. Uncertainties related to electricity markets, as well as RVPP RES units and demands, are considered in the RVPP optimization problem.**

***Index Terms*—Battery energy storage systems, renewable-only virtual power plant, electricity market, uncertainty.**

I. INTRODUCTION

BATTERY Energy Storage Systems (BESSs) are rapidly gaining attention for enhancing Renewable Energy Sources (RESs) integration, thanks to their ability to provide both active and reactive power regulation with response times as fast as tens of milliseconds [1]. Technological advances and the modular design of BESSs offer significant flexibility, enabling installations as large as 400 MW with capacities exceeding 1600 MWh, such as the Moss Landing BESS in California, USA, commissioned by Vistra Energy Corporation in 2021 [2]. The ability of BESSs to deliver a wide range of ancillary services and help balance the variability of RESs, combined with the gradual reduction in their cost per MW and MWh, has made them a popular solution for boosting RESs competitiveness [3]. However, several factors limit the large-scale BESS integration into power grids, such as high initial capital costs, relatively short lifespans depending on use (typically up to 7 years or a few thousand cycles), self-discharge rates of up to several percent per day of their State of Charge (SoC), limited availability of construction materials, and significant environmental impacts at the end of their life cycle [4].

An alternative to BESS to increment the penetration levels of RESs and to enhance their flexibility and economic viability is RES-only Virtual Power Plant (RVPP) [5]. An RVPP integrates a cluster of RESs to participate in electricity markets as a unified entity capable of providing grid services typically provided by large, centralized plants. This coordinated approach helps address the challenges associated with Non-dispatchable Renewable Energy Sourcess (ND-RESs), such as inherent variability and lack of firmness [6].

To increase the competitiveness of an RVPP, it is crucial to incorporate various market types and uncertainties into the RVPP optimization problem. The Day Ahead Market (DAM) serves as the primary revenue source for the RVPP across multiple markets, making it a focal point in several studies of RVPPs operation and market participation [7]–[9]. In the event of power imbalances due to, e.g., equipment outages or sudden load increases, the Secondary Reserve (SR) or Automatic Frequency Restoration Reserve (aFRR) is deployed to restore the frequency and the area power exchange to their reference values. In real time, Transmission System Operator (TSO) assigns the aFRR requirement for each zonal controller according to the cleared relative regulation band, with each zone directing its units to provide reserves as needed [10]. RVPPs would allow stochastic ND-RESs to compensate for their inherent power output variations, and meet the unlimited time reserve provision requirement. Given the alignment of SR service with security and timing requirements for market provisioning, RVPP participation in the Secondary Reserve Market (SRM) has been extensively studied in works such as [11]–[13].

To assess the economic performance of an RVPP [14], it is also essential to incorporate uncertainty characterization. Key uncertainties in RVPP studies typically include electricity prices across various markets, the output power of ND-RES, and demand profiles [15]. The Robust Optimization (RO) method is an effective approach to dealing with such uncertainties because it accounts for a wide range of parameter variations, provides feasible results, and is computationally efficient. RO aims to address the worst-case scenario to minimize the negative impact of uncertainties on the solution [16]. In flexible RO, the RVPP operator can define a preferred level of conservatism through an input parameter called the *uncertainty budget*, which determines the number of hours the optimization problem selects the worst cases of uncertain parameters [17]–[19].

To the authors' knowledge, although there is extensive research on the economic performance of RVPPs, a comparative analysis between BESS and RVPP is missing in the literature. This paper addresses this gap by determining the required BESS size to achieve comparable operational performance to

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an RVPP for different energy and reserve market participation. The required BESS size varies based on the RVPP operator's level of conservatism regarding uncertainties, as well as operational factors for the RVPP, such as weather conditions. To achieve this, the RO bidding model developed by the authors in [17] is applied in this work to represent the RVPP bidding problem in both the DAM and SRM. This model allows the RVPP operator to perform various parametric analyses efficiently and accurately. Simulation results show interesting findings that can help operators decide whether buying and installing a new BESS system is actually the best option, or if instead, a simple yet effective coordination of some, a priori, non-reliable assets can become the solution sought.

II. ROBUST FORMULATION

The results presented and analyzed in this paper for the RVPP have been obtained using the flexible robust bidding model introduced by the authors in [17]. The model for BESS participation in both energy and reserve markets is taken from [20]. Key points regarding the optimization models used for RVPP and BESS are summarized below.

RVPP Uncertainties in the Objective Function: The objective function of the flexible robust optimization problem maximizes the RVPP's profit from bidding in the DAM and SRM, subtracting operation costs while taking into account the adverse effects of electricity price uncertainties. To define worst-case scenarios of uncertainties, only negative deviations of the SRM reserve price are considered, since positive deviations would benefit the RVPP. For DAM electricity price forecasts, both positive and negative deviations are included, as the worst case may vary depending on whether the RVPP is a net seller or buyer of energy in a given period.

RVPP Uncertainties in Constraints: Uncertainties in the production of ND-RES and Solar Thermal Unit (STU) units, as well as fluctuations in demand, are modeled within the constraints of the optimization problem. To define worst-case scenarios, only negative deviations in the production of ND-RES units and the thermal output of the STU solar field are considered. Likewise, only positive deviations in demand are treated as worst-case scenarios, since negative deviations in demand generally benefit the RVPP.

Uncertainty Budget: The number of periods in which uncertainty parameters—such as DAM and SRM electricity prices, ND-RES and STU production, and demand consumption—deviate from their median to the worst-case value within the uncertainty distribution is controlled by a user-defined parameter known as the uncertainty budget.

BESS Model: The BESS model accounts for charging and discharging power over successive time periods, SR provisioning, SR ramping capability, reserve activation possibility, and SoC in each time period based on the energy level of the BESS.

BESS Infeasibility Issues: A certain amount of energy for up or down reserve provision is allocated according to the needs of the BESS operator to avoid infeasibility issues. These issues are addressed by separating the BESS energy for power provision and reserve. As a result, the formulation ensures that the BESS maintains the expected energy levels in real-time operation.

III. SIMULATION RESULTS

A. Data

This section presents the various data used to define the case studies in this paper. The data includes network topologies, RVPP portfolio configuration, unit capacities, costs, and other techno-economic characteristics, as well as uncertainty profiles such as price fluctuations and energy sources. The RVPP considered here is based on the model in [6] and is illustrated in Fig. 1. The RVPP is distributed over a 12-node network, representing, without loss of generality, a region in Southern Europe (Spain). In accordance with realistic scenarios, not all network units are part of the RVPP. The RVPP includes two Dispatchable Renewable Energy Sources (D-RESs) (a hydro plant at bus 6 and a biomass plant at bus 9), three ND-RESs (a wind farm at bus 4, solar PV1 at bus 8, and solar PV2 at bus 11), an STU (at bus 1), and three flexible demands (industrial demand at bus 3, airport demand at bus 9, and residential demand at bus 12). The capacity and operation costs of the RVPP units are summarized in Table I.

The forecast data for solar irradiation—and thus the available solar power production for PV plants and the STU—for different sample days of the Spanish spring season (representing both sunny and cloudy days) are obtained from the forecasting tool presented in [21]. The wind production forecast for a sample spring day in Spain is obtained from [22]. All forecast data for RVPP ND-RES units, including PV plants, the STU, and the wind farm, are shown in Fig. 2. For each flexible demand, three different demand profiles are available for selection in the DAM, each with associated uncertainties as shown in Fig. 3. A 10% demand flexibility tolerance is allowed by the demand owner for further adjustments. More details on the demand flexibility model can be found in [23]. The forecast bounds for DAM electricity prices and SRM reserve prices for a sample day in the Spanish network are shown in Fig. 4. All price data are taken from the Spanish TSO website [24]. The primary economic and technical specifications of a 0.5 MW/1 MWh Lithium-Ion BESS block are provided in Table II [25]. For simplicity and comparability in the studies presented here, larger BESSs are approximated by proportional scaling of the values in Table II.

TABLE I: RVPP units capacity and operation cost [6].

RVPP Unit	Capacity [MW]	Operation cost [€/MWh]
Hydro plant	40	7.5
Wind farm	50	10
Solar PV1	50	5
Solar PV2	50	5
STU	50	15
Biomass plant	10	23

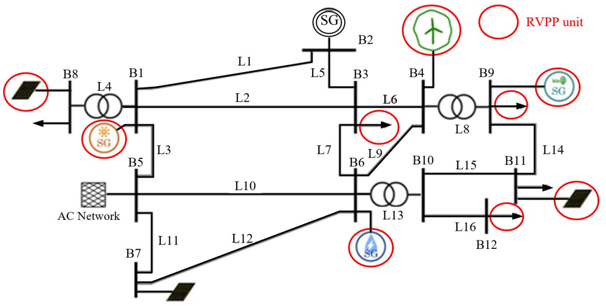

Fig. 1: Southern-Europe (Spanish) 12-node network and RVPP units [6].

TABLE II: Lithium-Ion BESS data [25].

Total cost [k€]	Energy capacity [MWh]	Ch./disch. capacity [MW]	Slope of expec. life [-]	Ch./disch. efficiency [%]	Self-disch. rate [%]
300	1	0.5	0.001	95	1

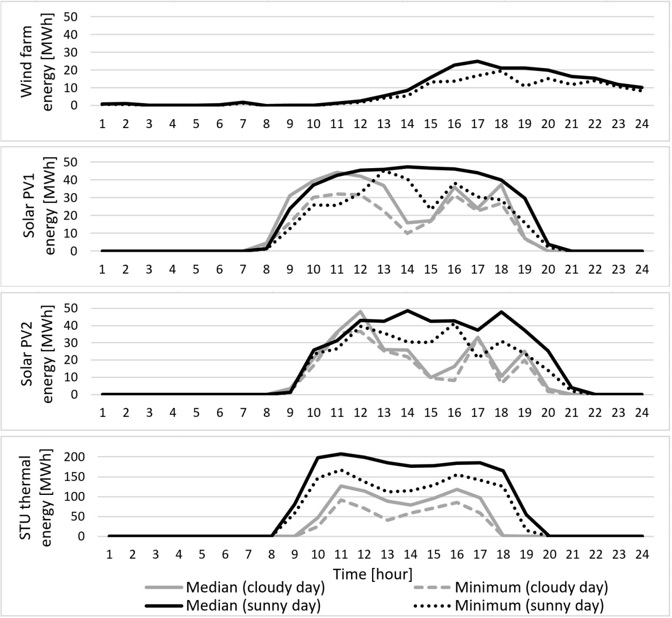

Fig. 2: RVPP ND-RES units energy forecast bounds [21], [22].

B. Description of Case Studies

In this section, four different case studies are defined, as outlined in Table III, based on various characteristics and conditions relevant to RVPP. These cases are designed to assess the viability of RVPPs compared to alternative BESS-based solutions in the Southern Europe network. The first condition examined is the market participation strategy, determined by the robustness strategy of the RVPP operator in response to uncertainties (optimistic, balanced, and pessimistic strategies). In the optimistic scenario, the forecasts are assumed to be accurate, matching the median values of uncertain parameters. In the balanced scenario, deviations from the median are allowed for a limited number of periods (3 hours), specifying the hours that result in the worst outcomes for each uncertain parameter. In the pessimistic scenario, these deviations occur in more periods (8 hours). The second condition considers the market participation rules that can be set by the system operator regarding aggregation as an offering unit: (i) No coordination, where no aggregation of units is allowed for market participation; (ii) Coordination, where any flexible generation or demand unit can be aggregated; and (iii) the BESS based alternative solution (No coordination + BESS). Finally, the third condition relates to the weather, which is defined according to the predominant stochastic renewable source in each scenario.

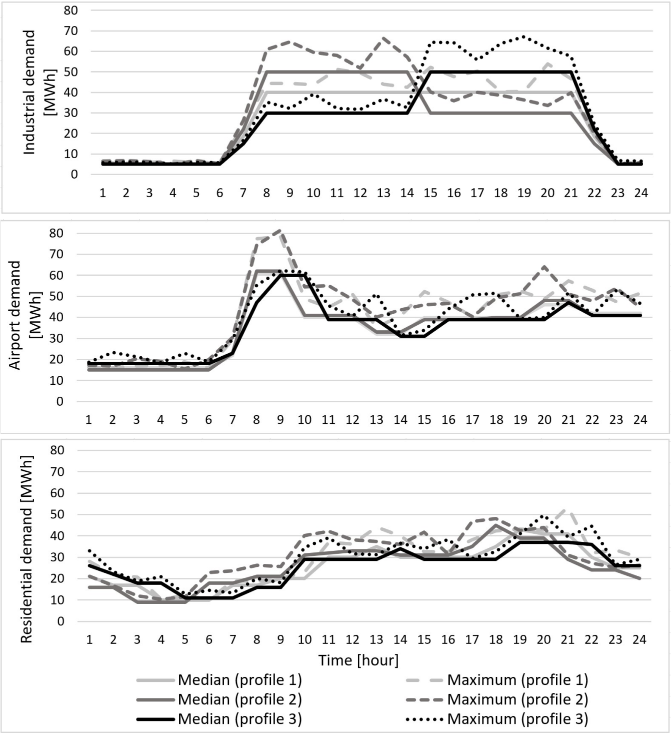

Fig. 3: RVPP demands energy forecast bounds [23].

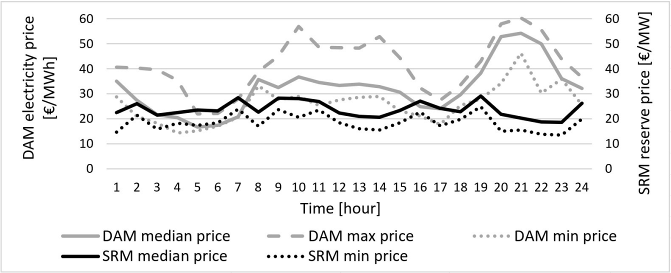

Fig. 4: DAM electricity price and SRM reserve price forecast bounds [24].

C. Case Studies

Table IV shows different economic factors for each individual unit, the sum of each economic factor for all units (no aggregation is allowed), and the economic factors when these units are aggregated as an RVPP in case studies 1-4. Profit is calculated as incomes minus all operation and robust

TABLE III: Description of case studies.

Characteristic		**Case study**			
		1	**2**	**3**	**4**
Strategy	**Optimistic**	✓	-	-	-
	Balanced	-	✓	-	✓
	Pessimistic	-	-	✓	-
RVPP portfolio	**No coordination**	✓	✓	✓	✓
	Coordination	✓	✓	✓	✓
	No coordination + BESS	✓	✓	✓	✓
Weather	**Sunny**	✓	✓	✓	-
	Cloudy	-	-	-	✓

costs. The income is derived from the bidding in the DAM and SRM. The operation costs reflect the cost of operating the units in the proposed dispatch, while the robust costs account for additional expenses due to fluctuations in DAM and SRM prices caused by uncertainty. The results show that the adoption of a more conservative strategy (comparing case 1 with cases 2 and 3) leads, expectedly, to a decrease in profit for each individual unit.

According to Table IV, the RVPP yields additional profits of 1.42k€, 2.55k€, 3.27k€, and 3.15k€ compared to the non-aggregated solution in case studies 1-4, respectively. The extra profits in cases 2 and 3 are 79% and 130% higher than the additional profit in case 1, indicating that the aggregation of units as an RVPP leads to a more substantial profit increase when considering cases with higher forecast deviations and uncertainties. Furthermore, the profit increase in case 4 under cloudy weather conditions is 24% higher than in case 2 under sunny conditions, highlighting the importance of RVPP in more challenging weather scenarios.

The extra profit obtained in each case study can be used to determine the BESS capacity required to achieve similar results as the coordination solution. Multiple 1 MWh BESS modules, as shown in Table II, can be aggregated to achieve a desired capacity. Table V compares the capacity, profit (measured as the difference between having BESS or not having BESS in the total DAM+SRM profit), and different costs of BESS for cases 1-4. Using larger BESSs leads to higher profit, but also to higher cost. In cases 1-4, a BESS with a capacity of 16 MWh, 30 MWh, 43 MWh, and 37 MWh, respectively, is needed to match the profit achieved by the RVPP. The relative profits for each BESS in Table V are close to the profit increases of 1.42k€, 2.55k€, 3.27k€, and 3.15k€ from the RVPP solution in cases 1-4. This indicates that more pessimistic scenarios or severe weather conditions require a larger BESS capacity to achieve comparable results. In addition, the need to increase in BESS capacity to achieve higher profits does not increase linearly in the balanced and pessimistic cases 2 and 3 compared to case 1. This indicates that achieving a higher relative profit in the balanced and pessimistic scenarios (cases 2 and 3) requires a proportionally larger increase in BESS capacity. The reason for this is that as uncertainty increases, it becomes more difficult to achieve a higher profit. A similar observation can be made when comparing case 4, with cloudy weather, to case 2, with sunny weather.

Figure 5 shows the energy traded by the BESS and the up/down SR for cases 1-4. In case 1, the BESS sells energy during hours 1-2, 4, 8, 10-13, 15, 18, 20-22, and 24, while buying electricity from the market during other hours. The BESS generally sells or buys less energy than its full discharging/charging capacity of 8 MW in most hours in order to maintain reserve availability. It prioritizes providing around 1 MW of upward reserve in most of the periods. In cases 2 and 3, there are some changes in the traded energy and SR compared to case 1 due to the consideration of the electricity price uncertain parameters. In these cases, the BESS sells energy in hours 1-2, 4, 8-13, 15, 19-22, and 24, while it buys in other periods. The BESS provides about 2 MW and 3 MW of upward reserve in cases 2 and 3, respectively, which are higher than in case 1. In case 4, the BESS increases both the traded energy and the SR compared to case 2 to mitigate the adverse effects of cloudy weather.

Figure 6 shows the BESS SoC along with its charging and discharging power in cases 1-4. In case 1, the BESS SoC peaks twice, between hours 5-9 and 17-20, as the BESS typically charges during these hours to store energy for periods with higher electricity prices. In cases 2 and 3, the SoC exhibits two sharper peaks due to increased discharge power, occurring between hours 5-7 and 16-18. Here, the BESS discharges for more hours and at higher levels than in case 1 to counteract uncertainties. A similar pattern appears in case 4, compared to case 2, where both the charging and discharging power of the BESS are intensified.

IV. CONCLUSION

This paper identifies the required BESS capacity needed to achieve comparable economic performance to an RVPP in energy and reserve markets under varying levels of uncertainty and weather conditions. The results show that the adoption of more conservative strategies leads to a reduction in the overall profit, driven by the effects of worst-case forecast errors in the optimization problem. However, relatively, higher differences between having a RVPP or not in such profits were also observed as the robustness level increases. This leads to larger BESS in order to obtain similar economic results as with the same RVPP. In other words, as more conservative approaches are used to manage price and energy uncertainties, the RVPP solution becomes increasingly valuable—a noteworthy finding that also holds under unfavorable weather conditions.

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TABLE IV: Units profit and costs in cases 1-4.

Units	**Profit [k€]**				**Incomes [k€]**				**Operation Cost [k€]**				**Robust Cost [k€]**			
	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 1**	**Case 2**	**Case 3**	**Case 4**
Hydro plant	26.29	24.10	21.36	24.10	32.54	32.41	32.23	32.41	6.25	6.22	6.16	6.22	0	2.09	4.69	2.09
Biomass plant	3.47	2.98	2.51	2.98	7.43	7.23	6.01	7.23	3.95	3.82	2.95	3.82	0	0.41	0.54	0.41
Wind farm	5.79	4.72	3.81	4.72	7.58	6.78	6.03	6.78	1.79	1.52	1.34	1.52	0	0.53	0.87	0.53
Solar PV1	13.32	9.53	6.66	6.94	15.25	13.43	11.57	9.89	1.93	1.66	1.36	1.21	0	2.23	3.55	1.73
Solar PV2	13.05	10.06	6.88	5.64	14.90	13.41	11.54	8.08	1.84	1.58	1.34	0.98	0	1.76	3.30	1.46
STU	16.72	12.72	9.06	6.93	26.63	21.74	15.24	10.41	9.91	7.62	4.28	2.54	0	1.39	1.89	0.93
Industrial demand	-22.09	-25.48	-28.46	-25.48	-22.09	-23.58	-24.81	-23.58	0	0	0	0	0	1.89	3.65	1.89
Airport demand	-28.92	-32.78	-37.09	-32.78	-28.92	-30.54	-32.76	-30.54	0	0	0	0	0	2.23	4.32	2.23
Residential demand	-21.31	-24.42	-27.10	-24.42	-21.31	-22.62	-23.83	-22.62	0	0	0	0	0	1.80	3.26	1.80
Total	**6.34**	**-18.55**	**-42.34**	**-31.35**	**32.04**	**18.26**	**1.22**	**-1.92**	**25.70**	**22.44**	**17.45**	**16.31**	**0**	**14.37**	**26.11**	**13.10**
RVPP	**7.76**	**-16.00**	**-39.07**	**-28.20**	**32.59**	**18.92**	**2.06**	**-1.05**	**24.83**	**21.86**	**17.27**	**15.60**	**0**	**13.06**	**23.86**	**11.53**

TABLE V: BESS results that mimic the economic performance of RVPP in cases 1-4.

Case study	Capacity [MWh]	Relative profit [k€]	Incomes [k€]	BESS cost [k€]	Robust cost [k€]
1	16	1.45	1.52	0.06	0
2	30	2.53	2.81	0.11	0.17
3	43	3.26	4.03	0.16	0.60
4	37	3.12	3.47	0.14	0.21

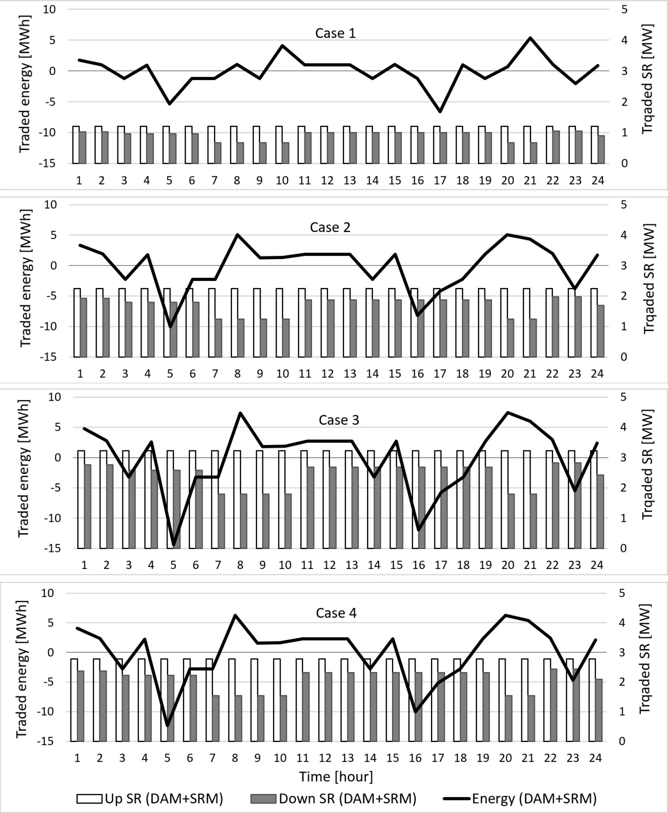

Fig. 5: BESS traded energy and SR in cases 1-4.

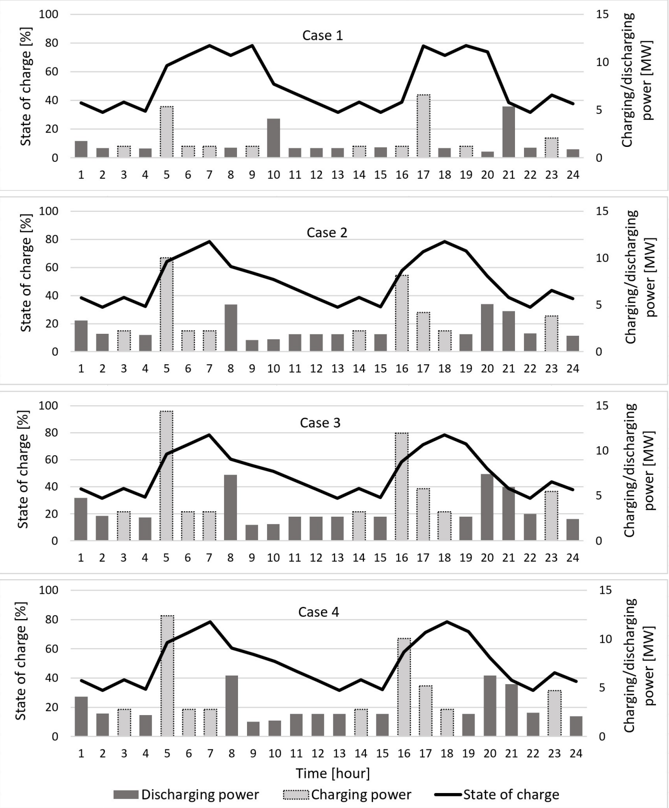

Fig. 6: BESS SoC and charging/discharging power in cases 1-4.

REFERENCES

[1] ENTSO-E, "Supporting document for the network code on load frequency control and reserves," ENTSO-E: Brussels, Belgium, June 2013, Tech. Rep., 2023.

[2] D. Reber, S. R. Jarvis, and M. P. Marshak, "Beyond energy density: flow battery design driven by safety and location," *Energy Advances*, vol. 2, no. 9, pp. 1357–1365, 2023.

[3] K. Prakash, M. Ali, M. N. I. Siddique, A. A. Chand, N. M. Kumar, D. Dong, and H. R. Pota, "A review of battery energy storage systems for ancillary services in distribution grids: Current status, challenges and future directions," *Frontiers in Energy Research*, vol. 10, p. 971704, 2022.

[4] K. Mongird, V. V. Viswanathan, P. J. Balducci, M. J. E. Alam, V. Fotedar, V. Koritarov, and B. Hadjerioua, "Energy storage technology and cost characterization report," Pacific Northwest National Laboratory (PNNL), Richland, WA (United States), Tech. Rep., 2019.

[5] H. Nemati, P. Sánchez-Martín, A. Baringo, and Á. Ortega, "Single-level robust bidding of renewable-only virtual power plant in energy and ancillary service markets for worst-case profit," *arXiv preprint arXiv:2403.02953*, 2024.

[6] Á. Ortega, O. Oladimeji, H. Nemati, L. Sigrist, P. Sánchez-Martın, L. Rouco, E. Lobato, M. Biencinto, and I. López, "Modeling of VPPs for their optimal operation and configuration," *POSYTYF Consortium, Tech. Rep*, 2022.

[7] D. Fernández-Muñoz and J. I. Pérez-Díaz, "Optimisation models for the day-ahead energy and reserve self-scheduling of a hybrid wind–battery virtual power plant," *Journal of Energy Storage*, vol. 57, p. 106296, 2023.

[8] X. Wei, Y. Xu, H. Sun, X. Bai, X. Chang, and Y. Xue, “Day-ahead optimal dispatch of a virtual power plant in the joint energy-reserve-carbon market,” *Applied Energy*, vol. 356, p. 122459, 2024.

[9] A. A. Bafrani, A. Rezazade, and M. Sedighizadeh, “Robust electrical reserve and energy scheduling of power system considering hydro pumped storage units and renewable energy resources,” *Journal of Energy Storage*, vol. 54, 2022.

[10] I. Egido, F. Fernandez-Bernal, and L. Rouco, “The spanish AGC system: Description and analysis,” *IEEE Transactions on Power Systems*, vol. 24, no. 1, pp. 271–278, 2009.

[11] H. Wang, S. Riaz, and P. Mancarella, “Integrated techno-economic modeling, flexibility analysis, and business case assessment of an urban virtual power plant with multi-market co-optimization,” *Applied Energy*, vol. 259, p. 114142, 2020.

[12] S. Sadeghi, H. Jahangir, B. Vatandoust, M. A. Golkar, A. Ahmadian, and A. Elkamel, “Optimal bidding strategy of a virtual power plant in day-ahead energy and frequency regulation markets: A deep learning-based approach,” *International Journal of Electrical Power & Energy Systems*, vol. 127, p. 106646, 2021.

[13] J. Naughton, H. Wang, M. Cantoni, and P. Mancarella, “Co-optimizing virtual power plant services under uncertainty: A robust scheduling and receding horizon dispatch approach,” *IEEE Transactions on Power Systems*, vol. 36, no. 5, pp. 3960–3972, 2021.

[14] H. Nemati, P. Sánchez-Martín, L. Sigrist, L. Rouco, and Á. Ortega, “Flexible robust optimization for renewable-only VPP bidding on electricity markets with economic risk analysis,” *International Journal of Electrical Power & Energy Systems*, vol. 167, p. 110594, 2025.

[15] S. Yu, F. Fang, Y. Liu, and J. Liu, “Uncertainties of virtual power plant: Problems and countermeasures,” *Applied Energy*, vol. 239, pp. 454–470, 2019.

[16] N. Naval and J. M. Yusta, “Virtual power plant models and electricity markets-a review,” *Renewable and Sustainable Energy Reviews*, vol. 149, p. 111393, 2021.

[17] H. Nemati, P. Sánchez-Martín, Á. Ortega, L. Sigrist, E. Lobato, and L. Rouco, “Flexible robust optimal bidding of renewable virtual power plants in sequential markets,” *arXiv preprint arXiv:2402.12032*, 2024.

[18] J. Wang, V. Ilea, C. Bovo, N. Xie, and Y. Wang, “Optimal self-scheduling for a multi-energy virtual power plant providing energy and reserve services under a holistic market framework,” *Energy*, vol. 278, p. 127903, 2023.

[19] L. Silva-Rodriguez, A. Sanjab, E. Fumagalli, and M. Gibescu, “Light robust co-optimization of energy and reserves in the day-ahead electricity market,” *Applied Energy*, vol. 353, p. 121982, 2024.

[20] H. Nemati, L. Sigrist, L. R. Rodríguez, P. Sánchez-Martín, and Á. Ortega, “Addressing unfeasibilities of energy storage systems participating in energy and reserve markets,” in *2022 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe)*. IEEE, 2022, pp. 1–5.

[21] M. Biencinto, L. González, and L. Valenzuela, “Using time-windowed solar radiation profiles to assess the daily uncertainty of solar thermal electricity production forecasts,” *Journal of Cleaner Production*, vol. 379, p. 134821, 2022.

[22] Iberdrola, “Wind production forecast.” [Online]. Available: {https://www.iberdrola.es/.}

[23] O. Oladimeji, Á. Ortega, L. Sigrist, P. Sánchez-Martín, E. Lobato, and L. Rouco, “Modeling demand flexibility of RES-based virtual power plants,” in *2022 IEEE Power & Energy Society General Meeting (PESGM)*. IEEE, 2022, pp. 1–5.

[24] Red Eléctrica de España, “Electricity price forecast.” [Online]. Available: {https://www.esios.ree.es/en/analysis/634}

[25] M. R. Sarker, H. Pandžić, K. Sun, and M. A. Ortega-Vazquez, “Optimal operation of aggregated electric vehicle charging stations coupled with energy storage,” *IET Generation, Transmission & Distribution*, vol. 12, no. 5, pp. 1127–1136, 2018.