

Modeling and Performance Analysis of Battery Energy Storage Incorporated Grid-Connected Photovoltaic Plants

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ABSTRACT

This study conducts a detailed performance comparison between two large-scale photovoltaic (PV) power plants, each with an installed capacity of 1 MW. One system follows a conventional PV configuration, while the other incorporates a battery energy storage system (BESS) for enhanced functionality. The BESS-integrated system employs a peak-shaving strategy, aiming to store excess energy generated beyond 1 MW during daytime hours. The primary goals are to extend the PV system's energy supply into peak demand periods following sunset and to improve responsiveness to energy demand fluctuations. Both configurations were independently modeled using the same simulation environment, with a focus solely on technical performance, excluding economic considerations. Simulation results reveal that the BESS-enhanced system delivers an additional 153.18 MWh annually to the grid and achieves a 4.8% improvement in performance ratio. These findings highlight the technical benefits of BESS integration in PV systems, particularly its contribution to improving energy continuity.

Batarya Enerji Depolama Sistemine Sahip Şebeke Bağlantılı Fotovoltaik Santrallerin Modellenmesi ve Performans Analizi

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Sorumlu Yazar

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Anahtar Kelimeler

FV sistemler

Tepe-traşlama

Enerji depolama

Batarya

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ÖZ

Bu çalışma, her biri 1 MW kurulu güce sahip iki büyük ölçekli fotovoltaik (FV) enerji santrali arasında ayrıntılı bir performans karşılaştırması yürütmektedir. Sistemlerden biri geleneksel bir PV konfigürasyonunu takip ederken, diğeri gelişmiş işlevsellik için bir batarya enerji depolama sistemi (BEDS) içermektedir. BEDS entegreli sistem, gündüz saatlerinde 1 MW'ın üzerinde üretilen fazla enerjiyi depolamayı amaçlayan bir tepe traşlama stratejisi kullanmaktadır. Birincil hedefler, PV sisteminin enerji arzını gün batımından sonraki tepe talep dönemlerine kadar uzatmak ve enerji talebi dalgalanmalarına duyarlılığı iyileştirmektir. Her iki konfigürasyon da aynı simülasyon ortamı kullanılarak, ekonomik hususlar hariç tutularak yalnızca teknik performansa odaklanılarak bağımsız olarak modellenmiştir. Benzetim sonuçları, BEDS ile geliştirilmiş sistemin şebekeye yıllık ek 153,18 MWh sağladığını ve performans oranında %4,8'lik bir iyileştirme sağladığını ortaya koymaktadır. Bu bulgular, özellikle enerji sürekliliğini iyileştirmeye katkısı olmak üzere, FV sistemlerine BEDS entegrasyonunun teknik faydalarını vurgulamaktadır.

1. INTRODUCTION

With the increasing population and developing industry in the world, the energy demand is increasing rapidly. A large part of the energy demand is still provided by fossil fuels. Fossil fuels create serious concerns for the society in terms of the sustainability targets. For this reason, the tendency towards renewable energy in the world is increasing day by day and official steps are being taken and targets are being determined in this regard. Finally, it is the transition to completely renewable energy and zero carbon emission. Although renewable energy sources are accepted as an unlimited energy source in theory, in practice, the dependence on fossil fuels still continues today due to the fact that energy continuity and never and instantly respond [1,2]. By nature, photovoltaic power plants (PV) can only produce energy when sunlight directly reaches the PV modules. Therefore, solar power plants only have the potential to generate electricity during daylight hours. They are also directly affected by momentary weather changes. This directly affects the power plant's output, i.e. the amount of energy injected into the grid. On the other hand, energy consumption, i.e. energy demand, differs from this production cycle. Energy demand usually reaches its highest levels in the early morning and evening hours. In this context, solar power plants have difficulty responding to this demand. Because these plants can only reach their highest generation capacity at noon in clear and sunny weather [3,4].

Recent developments in battery technology have created a serious potential for the attainability of the ultimate zero carbon emission target. In this context, it is aimed to store the excess energy in batteries as soon as it is produced and inject it into the grid during periods of high demand. In addition, excess energy that exceeds the maximum output power of the plant within the scope of the contract is also transferred to the batteries. For these reasons, applications have begun to integrate battery systems into photovoltaic power plants. In the coming years, it is expected that this integration will accelerate further with the decrease in battery unit costs [5].

The three most commonly used methods with energy storage systems (ESS) in PV power plants are peak shaving, self-consumption optimization and load shifting applications. Peak shaving aims to store the excess production remaining above the peak of the production license in batteries and integrate it into the grid during periods when production decreases during the day or during periods when demand increases after sunset. Self-consumption optimization increases the use of this energy directly in the facility by storing the excess electricity generated from solar energy in batteries and increases the on-site usage rate instead of selling it to the grid. Load shifting is an effective strategy to reduce energy costs by charging the battery during low-cost hours and discharging it during high-tariff periods; this provides a great advantage especially in systems where time-of-use (TOU) tariffs are applied. These three methods are the most common and profitable applications of PV+BESS integration in terms of both energy efficiency and economic return [6].

In addition, battery energy storage systems (BESS) significantly facilitate the grid integration of PV systems. PV systems have an inherently variable and intermittent generation profile, which can lead to problems with grid frequency and voltage stability, especially during sudden generation changes such as cloud transitions. While this variability complicates direct integration into the grid, BESS solutions compensate for such fluctuations, making PV system outputs more stable and predictable. With services such as ramp rate control, frequency regulation and voltage support, BESS enables the safe and stable integration of PV systems into the grid. BESS integration to PV systems and grid integration of these systems has been a very popular research and development topic in recent years [7].

Rodriguez-Gallegos et al. conducted a study on the cost and benefit analysis of storage and non-storage systems in different geographical regions [8]. Okafor et al. presented a study on the techno-economic analysis of the integration of BESS into on-grid PV system [9]. Sharma et al. performed a comparative analysis of different battery technologies and discussed to determine the most suitable size for solar power plant applications [10]. Li et al. investigated performance of lithium-ion batteries in solar power plants in detail [11]. Rouholamini et al. examined the annual generation and grid interaction of grid-connected solar power plants with and without energy storage systems [12]. Hill et al. investigated the integration of solar energy into the system in order to overcome the problems that may arise from the intermittent nature of solar energy in the integration of these two systems as solar energy becomes more popular and the transition

to smart grids were examined [13]. Rahimi et al. conducted a study to discuss a simple method to achieve peak load reduction through energy storage systems for a utility [14]. Cervantes and Choobineh performed a study for optimal sizing of a nonutility-scale solar power system and battery energy storage system. Analysis shows that the size of the solar system is affected by labor cost and load size, while the battery storage size is sensitive to load size and battery cost [15]. Lange et al. performed a study for sizing battery energy storage systems for peak shaving based on a real-time control algorithm. A simulation environment to determine the behavior of the energy system, a real-time peak shaving control algorithm and a sizing process consisting of an optimization process to determine the battery algorithm parameters were proposed [16].

Consequently, this literature review focused on the performance analysis of on-grid PV systems with and without energy storage systems. The conducted literature survey show that energy storage systems have the potential to improve solar integration, increase grid stabilization and improve overall system efficiency. However, it is emphasized that local conditions, technological developments and economic factors should be carefully considered for optimal system design.

The primary objective of this study is to model and analyze the performance of grid-connected PV power plants integrated with BESS. The main focus is on enhancing energy dispatchability and grid interaction. By incorporating BESS into conventional PV systems, the research aims to evaluate how energy storage can mitigate the intermittent nature of solar energy, enable peak shaving, and improve system reliability during periods of high demand or low solar generation. Through comprehensive simulation-based modeling, the study investigates the impact of BESS integration on key performance metrics such as energy yield, performance ratio, and energy injected into the grid.

The rest of the paper is organized as follows: Section 2 presents material and methods. System description is performed in Section 3. In Section 4, the performance results of the PV power plant with and without battery energy storage system. Finally, conclusions are highlighted in Section 5.

2. MATERIALS AND METHODS

The simulation study for the Karacaören PV Power Plant project was carried out using a simulation software widely used in the sector. The system has a grid-connected structure and does not include a battery system, while the secondary project includes a BESS integrated into the same system.

The power plant is located in the Karacaören region of Karaman province in southern Türkiye. The geographic coordinates that used in the simulation are as follows [17]:

- Latitude: 37.50° North
- Longitude: 33.21° East
- Altitude: 1112 meters
- Time Zone: UTC+3

This location is quite suitable for photovoltaic energy production due to its high insolation potential. The meteorological data used in the simulation is based on the Meteonorm 8.1 dataset. These data are synthetic data based on multi-year averages between 2003-2010 and have 100% satellite coverage. Monthly average global horizontal irradiance (GlobHor) is taken as 1834 kWh/m² on an annual basis. The albedo value, which is the reflection coefficient of the ground surface, is defined as 0.20. This value is an average reflectivity ratio suitable for open terrain conditions.

The simulation software that used in this project is a professional simulation software widely used to perform performance analysis of photovoltaic systems. After the equipment used in the design stage were determined externally, the system configuration, energy production, system losses and annual performance rates in the Karacaören project are calculated by this software. The shadowing effect was not taken into account in the simulation and 3D scene definition was not made. Since the two variants are simulated in the same conditions, these ignored parameters have a minimal effect on the obtained results.

The photovoltaic panels used in the project are manufactured by HT-SAAE and the model name is HT66-18X-500. The fact that it is manufactured in a location close to the project area in Türkiye and after-sales support factors played an important role in the selection of this module. The basic technical features of the system are given in Table 1.

Table 1. Technical features of the system

Nominal power of modules at STC	500 W _p
Total number of modules	3060 units
Total installed PV power	1530 kW _p
Series connection configuration	170 strings x 18 modules

The output power of the system at 50°C operating temperature is calculated as 1406 kW_p. The operating voltage obtained at this temperature is 623 V and the current is 2256 A.

On the inverter side, Huawei Technologies' SUN2000-100KTL-M1-400Vac model was used. The reason for choosing this material is that it has proven itself with its previous versions as a string inverter and its after-sales support advantages. The basic technical features of the inverter configuration are presented in Table 2.

Table 2. The basic technical features of the inverter configuration

Unit power	100 kW _{ac}
Total number of inverters	11 units
Total AC power	1100 kW _{ac}
DC:AC power ratio	1.39
Operating voltage range	200 – 1000 V

The storage system is configured with BYD Battery Box Premium HVS 12.8 model batteries. The storage system features are given in Table 3.

Table 3. The storage system features

Total number of batteries	102 (2 series x 51 parallel)
Voltage	1024 V
Nominal capacity	1275 Ah
Total storage energy	1044.5 kWh
Minimum discharge level (SOC)	20%
Storage strategy	Peak shaving
Charge time	When grid power limit is exceeded
Discharge time	After sunset
Charger unit	380 kW _{dc} , 97% efficiency
Discharge inverter	280 kW _{ac} , 97% efficiency

The system without BESS integration is called Variant 0 (VC0), the system with BESS integration is called Variant 1 (VC1).

3. SYSTEM DESCRIPTION

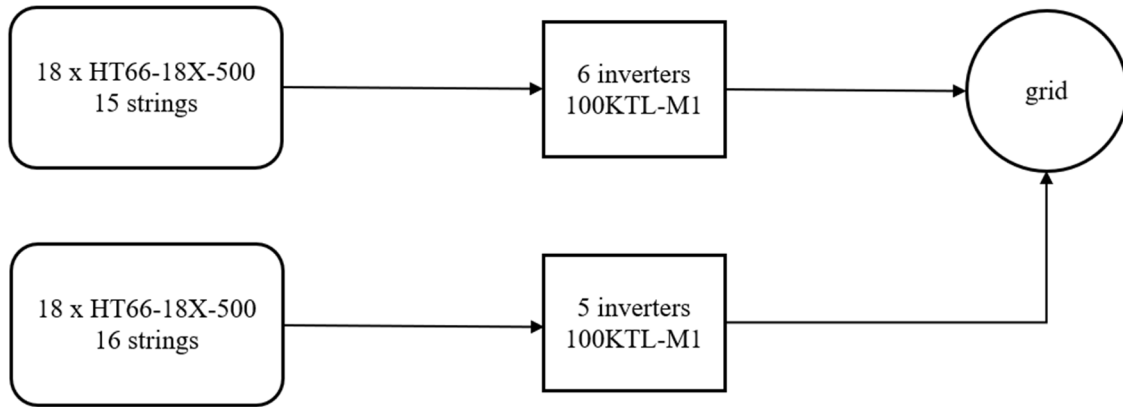
3.1. PV System without BESS and Peak Shaving

Karacaören PV Power Plant is configured as a grid-connected photovoltaic power plant with an installed capacity of 1530 kW_p. There is no BESS in this variant. The system is installed on a fixed inclined plane and shading factors are not taken into account. General system parameters are given in Table 4.

Table 4. General system parameters

Total PV power	1530 kW _p
PV module type	HT-SAAE HT66-18X-500 (500 W _p)
Number of modules	3060 pcs (170 strings × 18 modules)
Number of inverters	11 pcs
Total AC power	1100 kW _{ac}
System tilt / azimuth	32.5° / 0°
Load to grid	Unlimited
Albedo	0.20
Shading	No shadings

Single-line diagram of the constructed PV system without BESS is illustrated in Figure 1.

**Figure 1.** VC0 single line diagram

The limits of these inverters are depicted in Table 5.

Table 5. The limits of utilized inverters

Unit power	100 kW _{ac}
Total inverter power	1100 kW _{ac}
DC:AC power ratio	1.39
Operating voltage range	200 – 1000 V
Maximum output at rated power	110 kW _{ac} (at 33°C)

3.2. PV System with BESS and Peak Shaving

In this variant, the BESS system consisting of BYD Battery Box Premium HVS 12.8 model lithium-ion batteries are integrated into the PV system. The main purpose of the system is to ensure supply continuity, prevent instantaneous peaks and support grid loads.

Battery box general features are given in Table 6.

Table 6. Battery box general features.

Battery type	Lithium-ion
Model	BYD Battery Box Premium HVS 12.8
Total number of units	102 (2 series × 51 parallel)
Total storage capacity	1044.5 kWh
Nominal voltage	1024 V
Capacity	1275 Ah
Operating temperature	Fixed 20°C
Minimum discharge level (SOC)	20%

Single-line diagram of the constructed PV system with BESS is illustrated in Figure 2.

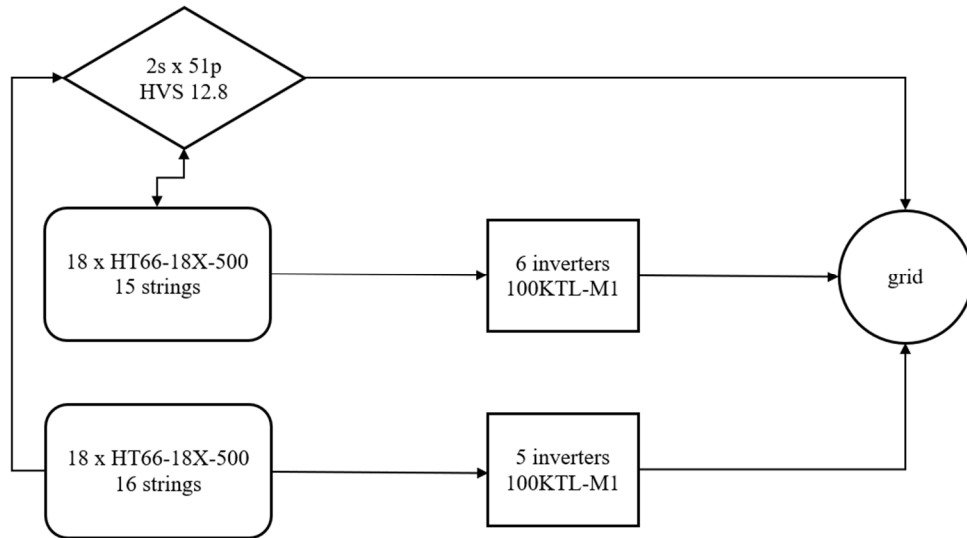


Figure 2. Variant 1 Single line diagram

Power conversion system is ignored in this project. The operating principle of BESS is determined as peak-shaving. With this strategy, excess energy beyond the grid limit is stored in batteries and injected into the grid when demand is high.

When the instantaneous output power of the PV system exceeds the 1000 kW threshold, the BESS is activated and stores the energy above this limit, while the discharge is active towards the grid after sunset. Charge/discharge parameters are given in Table 7.

Table 7. Charge/discharge parameters

Max. charge power	380 kWdc
Max. discharge power	280 kWdc
Efficiency	97% max

4. RESULTS AND DISCUSSIONS

Table 8 lists the monthly and annual total energy production data and performance ratios (PR) of the variants according to the simulation results:

Table 8. VC0/1 simulation results

Month	Production (kWh)-V0	Production (kWh)-V1	Production (%) - V0	Production (%) - V1
January	153,397	162,004	87.2	92.1
February	167,290	174,585	86.6	90.4
March	205,732	219,415	80.8	86.1
April	223,467	238,421	78.4	83.6
May	259,739	275,482	79.3	84.1
June	256,734	274,317	77.0	82.3
July	266,609	280,787	77.8	81.9
August	260,678	277,942	75.9	81.0
September	240,067	256,772	77.0	82.4
October	207,073	221,467	79.4	84.9
November	168,392	176,882	85.2	89.5
December	152,673	156,961	90.5	93.0
Total	2,561,851	2,715,034	80.2	85.0

It is calculated that 153.18 MWh is injected into the grid via BESS at VC1 after battery conversion losses, which cannot be injected into the grid at VC0 under normal conditions. It is also observed that VC1 offers 4.8% higher performance in terms of performance ratio.

When the daily power output curves are examined, it is seen that the power output at VC0 flattens out on clear days due to reaching its peak limit at noon as shown in Figure 3.

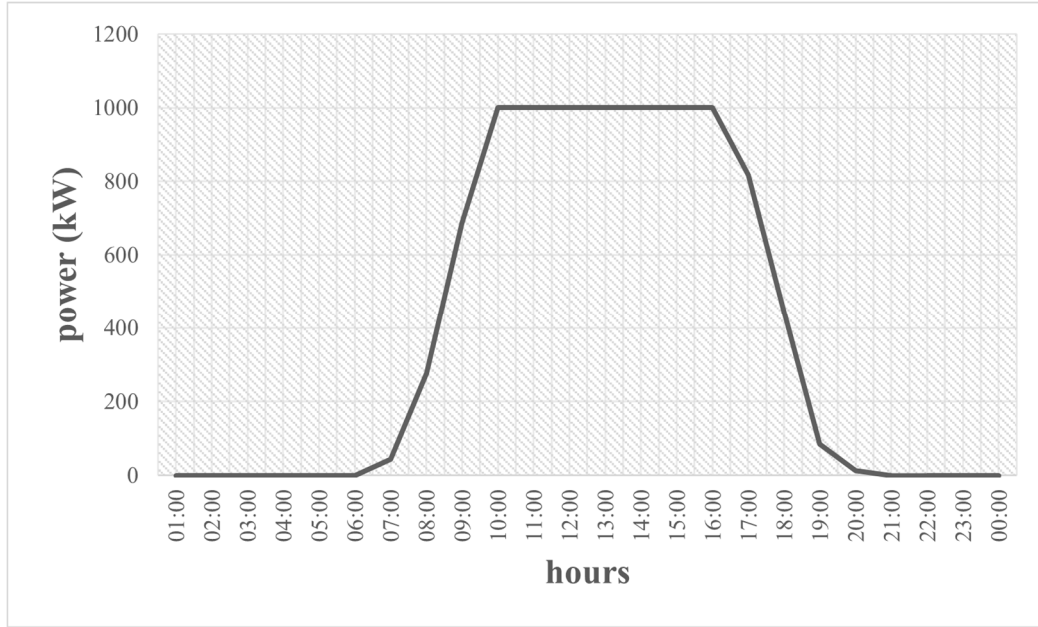


Figure 3. VC0 injected energy to grid in a clear sky day

The curve of the clear sky day presented for VC0 and the curve of the same day in the VC1 simulation are illustrated in Figure 4.

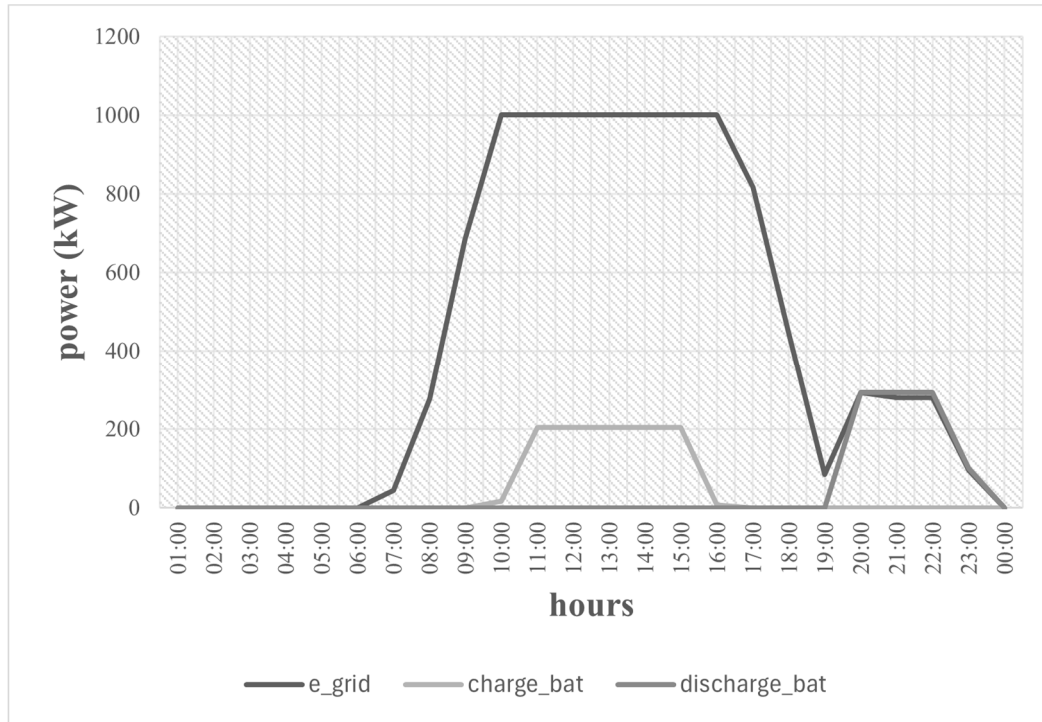


Figure 4. VC1 injected energy to grid in a clear sky day

When the daily power output curves are examined, it is seen that the power output in VC1 reaches its peak at noon and follows a horizontal course on clear days, while the energy remaining above the peak is charged to the batteries to be discharged in the evening.

When Figures 3 and 4 are compared, it is seen that VC0 cuts the power output increase when it reaches the grid injection point and is fixed at 1000 kW, that is, it limits the maximum output power to 1000 kW. However, since there is no limit criterion in VC1, the output power up to 1000 kW is injected into the grid, while the system keeps the output power fixed at 1000 kW without restricting itself for more energy output and stores the excess value in batteries to be injected into the grid after sunset when the energy supply increases. The simulation loss diagram for VC0 is presented in Figure 5.

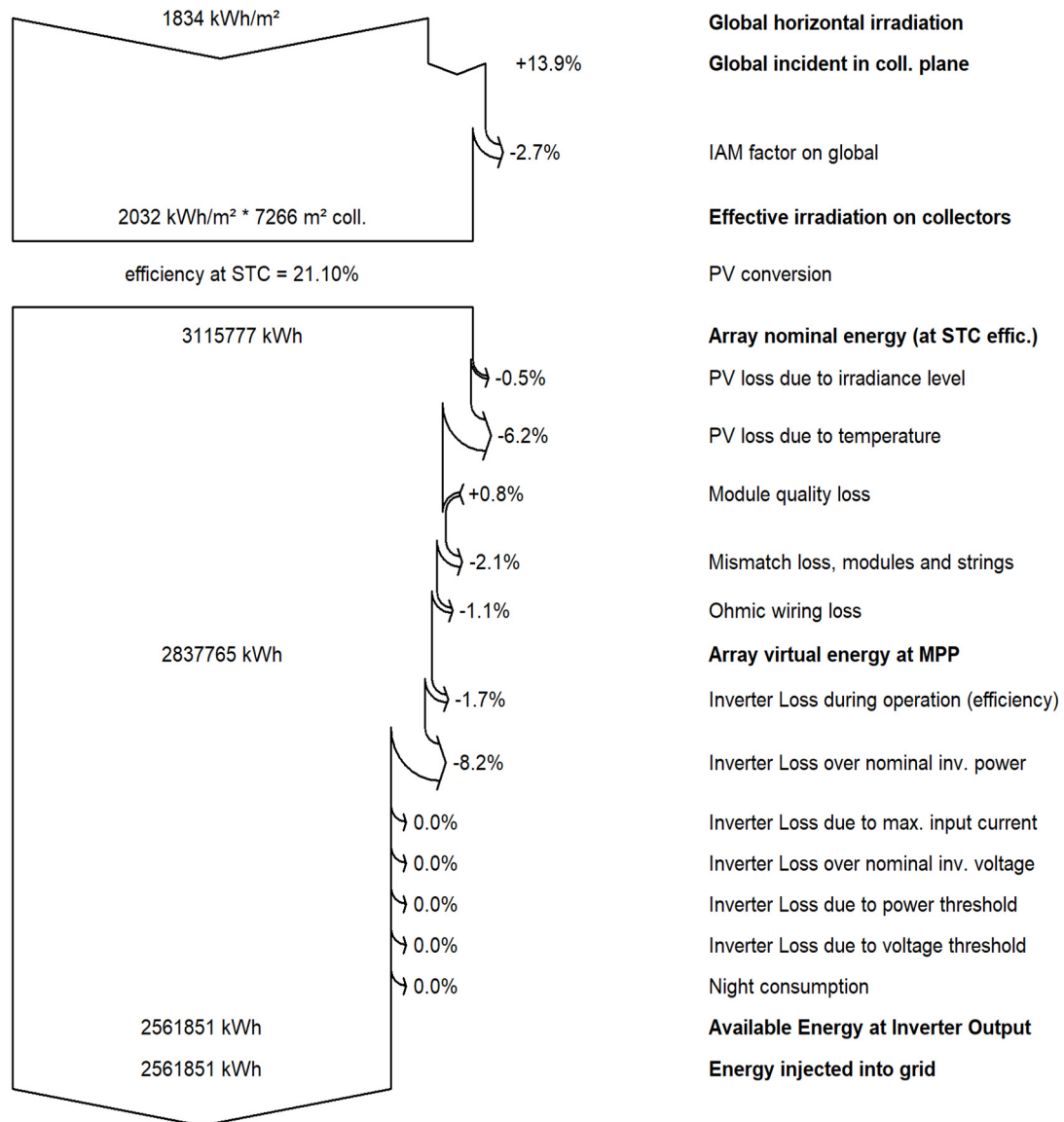


Figure 5. VC0 loss diagram

It has been determined that there is a serious loss at this point because the inverters cannot provide output power over 1000 kW and are limited according to the connection agreement. The simulation loss diagram for VC1 is presented in Figure 6.

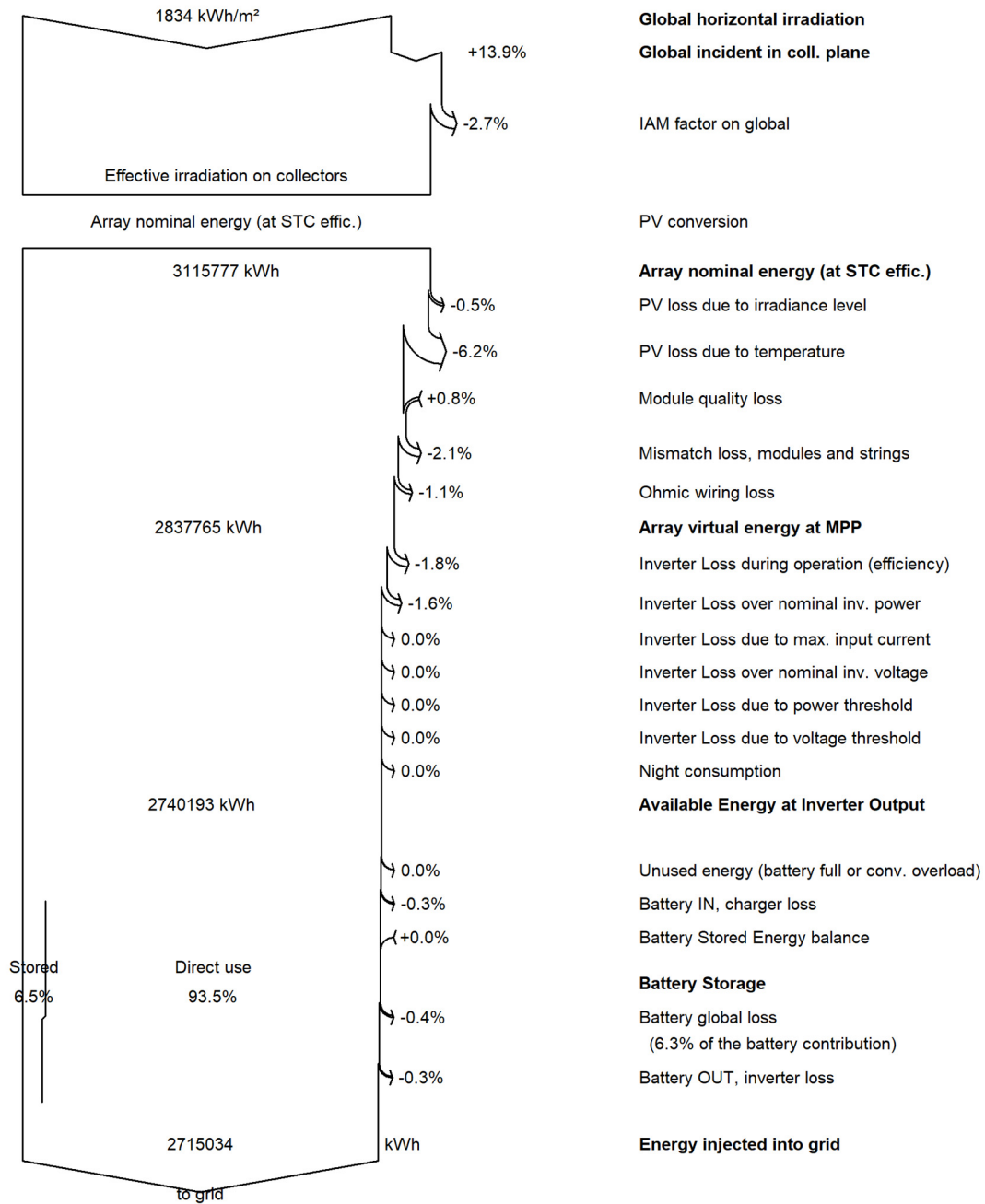


Figure 6. VC1 loss diagram

It is seen that the inverter nominal limit loss of 8.2% has decreased to 1.64% with the BESS integration and the system operates with less loss. In addition, it has been observed that the losses of the batteries during the charge/discharge cycle are in accordance with the battery label efficiency values and it is understood from the loss diagrams that the system operates stably.

As mentioned in the paragraph comparing Figures 3 and 4, on days with clear weather and long sunshine, the grid output power limitation in VC0 prevented the injection of more than 1000 kW into the grid, limiting the system and targeting a maximum output power of 1000 kW during this period. Therefore, VC0 remained below its current potential, meaning the energy it could generate. This is technically considered a loss. However, while 1000 kW was injected into the grid without any restrictions in VC1, no generation loss occurred as long as the remaining value did not exceed the maximum charging power, which is the threshold

value of 1380 kW for VC1 (1000 kW maximum grid injection power limit plus 380 kW maximum charging power). Based on this, the major loss item in Figures 5 and 6 can be explained.

It should be noted that there are many advantageous and disadvantageous of BESS assisted PV systems in technical, environmental, and economic perspectives. Providing energy time-shifting and peak shaving, reducing PV output fluctuations and curtailment, enhancing grid stability via frequency/voltage support, availability revenue from ancillary services, facilitating higher penetration of renewable energy for reducing greenhouse gas emissions make BESS integration an attractive option for modern power systems. However, limited cycle life and calendar degradation, requiring advanced energy management system and complex control structure, high initial investment cost and maintenance cost, safety issues, and recycling challenges makes them disadvantageous

5. CONCLUSION

This study focuses on the integration of BESS into PV systems in Karaman, Türkiye, and presents a comparison that focuses on technical efficiency without any economic concerns. The major goal is to provide a deeper technical understanding of the operational benefits and limitations of BESS-enhanced PV systems, offering valuable insights for optimizing system design, planning, and control strategies in modern renewable energy applications. Simulations were performed using the current software of a popular simulation program in the sector, without adding data manually, and with the correct data in the database of the software. First, VC0 was designed, then BESS was designed and integrated into the system with the peak-shaving method and the storage capacity that would work efficiently with VC0, and as a result, the VC1 variant was created. According to the simulation results of both variants, it is inferred that both systems work efficiently.

According to the simulation results obtained, BESS integration has provided significant benefits in terms of efficiency and grid stabilization to the PV system. In VC1, an increase of 153.2 MWh is observed compared to VC0, while a 4.8% increase is observed on the PR side. The main reason for these improvements is that the energy above the grid power limitation during peak of the inverters enters the useful energy class with VC1.

In different conditions and situations, for example; in a scenario where energy demand on the grid is high and supply is low, if hourly energy unit prices vary, it is possible in practice to pull the peak shaving limit below the grid power limitation so that BESS can store more and create supply during periods with high unit prices when demand is high.

In addition, regarding grid interaction, BESS strengthens the optimization of the PV system to the grid. Due to its nature, instant decreases and increases in the output power of PV systems can be seen depending on weather conditions. These situations can strain the grid frequency because keeping the grid frequency stable is the primary priority for energy continuity. In instant peak situations, BESS helps to keep the grid frequency constant by smoothing the power curve.

As a result, BESS integration has provided advantages to the PV system in many areas such as higher production and more efficient operation, and helping with grid frequency balancing. However, in order to be able to carry out such works, these advantages must be considered economically. Although large-scale battery systems are developing rapidly, they are relatively new technology and therefore they are quite costly materials, and operational expenses such as failure and maintenance should not be ignored because periodic maintenance and repairs are essential for the system to operate properly and stably, which creates additional labor and costs.

In addition, although there are now official regulations with almost complete boundaries for PV systems, it should not be ignored that the current regulations on BESS systems can be updated according to current conditions and situations. Since current regulations are in question, there is no financial energy purchase guarantee or additional support for current energy sales unit prices for BESS integrated PV systems in the location where the project is designed. Since these factors are techno-economic feasibility issues, it is recommended that the investment be made by the investor by examining the possible investments in detail in accordance with current regulations.

The environmental results of the BESS integration into PV systems are quite essential because, as mentioned at the beginning, the dependency on fossil fuels can only end when renewable energy sources become permanent energy sources. For this reason, the availability of batteries loaded with energy to respond to energy demand on-site can be interpreted as a promising step, although not completely at this stage, and it is possible to approach or reach the targeted zero carbon emission with the developing technology and official and social steps to be taken in this field in the coming years.

6. REFERENCES

1. Çelik, Ö. (2023). Analysis of current limiting algorithm with anti-windup control for transient stability of grid-forming converters. *Çukurova Üniversitesi Mühendislik Fakültesi Dergisi*, 38(3), 671-681.
2. Erişti, H., Akdağlı, A., Baldan, E. & Sarı, A. (2025). Investigation of panel efficiency in photovoltaic systems under partial shading and different pollution conditions: An experimental study. *Çukurova Üniversitesi Mühendislik Fakültesi Dergisi*, 40(2), 301-311.
3. Çelik, Ö., Zor, K., Tan, A. & Teke, A. (2022). A novel gene expression programming-based MPPT technique for PV micro-inverter applications under fast-changing atmospheric conditions. *Solar Energy*, 239, 268-282.
4. Çelik, Ö., Büyük, M. & Tan, A. (2022). Mitigation of power oscillations for energy harvesting capability improvement of grid-connected renewable energy systems. *Electric Power Systems Research*, 213, 108756.
5. Çelik, Ö. (2025). An efficient control scheme for operational performance enhancement of vehicular fuel cell integrated power system. *Journal of Power Sources*, 625, 235660.
6. Inaolaji, A., Wu, X., Roychowdhury, R. & Smith, R. (2024). Optimal allocation of battery energy storage systems for peak shaving and reliability enhancement in distribution systems. *Journal of Energy Storage*, 95, 112305.
7. Bozkurt, H., Çelik, Ö. & Teke, A. (2024). Power quality enhancement in hybrid PV-BES system based on ANN-MPPT. *Turkish Journal of Electrical Engineering and Computer Sciences*, 32(5), 662-681.
8. Gandhi, O., Kumar, D.S., Rodríguez-Gallegos, C.D. & Srinivasan, D. (2020). Review of stability and reliability implications on power systems with high PV penetration: Part II – Potential solutions and the way forward. *Renewable and Sustainable Energy Reviews*, 132, 110018.
9. Okafor, C. E., Gbadamosi, S. L., Krishnamurthy, S., Ratshitanga, M. & Moodley, P. (2025). Techno-economic analysis of battery storage technologies in distribution networks with integrated electric vehicles and solar PV systems. *Energy Reports*, 14, 579-599.
10. Sharma, D.D., Singh, S.N., Rajpurohit, B.S. & Longatt, F.G. (2015). Critical load profile estimation for sizing of battery storage system. In *Proceedings of the IEEE Power & Energy Society General Meeting*.
11. Li, H., Wang, L., Song, Y., Zhang, Z., Zhang, H., Du, A. & He, X. (2023). Significance of current collectors for high-performance conventional lithium-ion batteries: A review. *Advanced Functional Materials*, 33(49), 2305515.
12. Rouholamini, M., Wang, C., Nehrir, H., Hu, X., Hu, Z., Aki, H., Zhao, B., Miao, Z. & Strunz, K. (2022). A review of modeling, management, and applications of grid-connected Li-ion battery storage systems. *IEEE Transactions on Smart Grid*, 13(6), 4505-4524.
13. Hill, C.A., Such, M.C., Chen, D., Gonzalez, J. & Grady, W.M. (2012). Battery energy storage for enabling integration of distributed solar power generation. *IEEE Transactions on Smart Grid*, 3(2), 850-857.
14. Rahimi, A., Zarghami, M., Vaziri, M. & Vadhva, S. (2013). A simple and effective approach for peak load shaving using battery storage systems. *North American Power Symposium (NAPS)*, 1-5.
15. Cervantes, J. & Choobineh, F. (2018). Optimal sizing of a nonutility-scale solar power system and its battery storage. *Applied Energy*, 216, 105-115.
16. Lange, C., Rueß, A., Nuß, A., Öchsner, R. & März, M. (2020). Dimensioning battery energy storage systems for peak shaving based on a real-time control algorithm. *Applied Energy*, 280, 115993.
17. PVsyst SA, (c. 2022). *PVsyst Tutorials V7* [User's manual—Grid-connected systems].

