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IMPROVING THE EFFICIENCY OF HYBRID POWER SUPPLY SYSTEMS THROUGH THE INTEGRATION OF ENERGY STORAGE SYSTEMS

The paper analyzes the improvement of efficiency in hybrid power supply systems of enterprises through the integration of photovoltaic generation and energy storage systems with different dispatch control algorithms. Four operating scenarios are considered: grid-only power supply, the use of photovoltaic installations only, a hybrid mode with storage of excess generation in the energy storage system, and a mode with forecast-oriented charging of the energy storage system during off-peak tariff periods. The modeling was performed with hourly discretization, taking into account seasonal load profiles, solar generation, and battery degradation costs. Efficiency was evaluated based on total electricity costs, import and export volumes, as well as self-consumption and self-sufficiency indicators. The obtained results indicate that the integration of energy storage systems significantly increases the utilization of on-site generation and reduces grid dependence, while the application of tariff-oriented control algorithms provides additional economic benefits without altering the structure of solar energy consumption. At the same time, the proposed approach is applicable not only to systems with strongly differentiated electricity tariffs, but also to enterprise power supply conditions typical of Ukraine, where the economic effect of storage may be determined to a greater extent by increasing local renewable energy utilization, reducing dependence on external supply, and improving operational flexibility.

Keywords: *hybrid power supply system, photovoltaic generation, energy storage system, dispatch control, self-consumption, self-sufficiency.*

Introduction

The rapid transformation of the electric power sector, driven by the need to reduce greenhouse gas emissions, enhance energy resilience, and decrease dependence on fossil fuels, has led to a growing role of renewable energy sources (RES) in the structure of electricity generation. In the coming decades, a further increase in installed capacity based on renewable technologies-primarily photovoltaic (PV) systems and wind turbines-is expected. A significant driver of this process has been the substantial cost reduction of photovoltaic modules and power conversion equipment over the past decade, which has ensured the competitiveness of solar energy compared to conventional generation [1].

At the same time, the large-scale deployment of RES in distributed electrical networks and industrial power supply systems is accompanied by a fundamental limitation associated with the intermittent and stochastic nature of generation. In solar energy systems, daily cycles, meteorological conditions, and seasonal variations are decisive factors, leading to a mismatch between the electricity production profile and the load schedule. In the industrial sector, where continuity and quality of power supply directly affect technological processes, such discrepancies necessitate capacity reservation and improved controllability of energy flows. In this context, the development of local energy systems and microgrids naturally involves the integration of energy storage systems (ESS) [2].

The application of ESS within hybrid power supply systems (HPSS) expands operational optimization capabilities by enabling the accumulation of excess generation, load leveling, and controlled temporal redistribution of energy. Through ESS, functions such as peak shaving, load shifting, increased utilization of on-site renewable generation, and cost reduction via managed electricity imports under multi-zone tariffs can be implemented. However, the effectiveness of HPSS depends not only on the proper sizing of PV capacity and ESS energy capacity, but also on the quality of dispatch control algorithms, which should be based on a formalized mathematical model of the system [3]. Studies indicate that simplified or economically inconsistent control strategies lead to underutilization of RES potential, accelerated degradation of electrochemical storage elements, and reduced investment attractiveness of projects [4].

The problem of optimal power flow management in both autonomous and grid-connected hybrid systems remains an active area of research. The typical dispatch problem involves determining, at each time step, whether charging or discharging the ESS is appropriate, defining the volume of grid imports and exports (where permitted), and selecting operating modes of backup generation sources in order to minimize total costs while satisfying technical constraints. Historically, the scientific literature has established several basic heuristic strategies that have served as a foundation for further development of optimization methods [5]. One of the simplest approaches is the load-following strategy, in which the external grid or local generator compensates only the difference between demand and current PV generation, while ESS charging is allowed exclusively from surplus solar energy. Although this strategy increases the share of “clean” energy in the charging balance, it often results in prolonged operation of the ESS near the minimum state of charge, reducing supply reliability in the presence of load fluctuations or power interruptions [2,5]. An alternative is the cycle-charging strategy, which involves intensive ESS charging when the system is forced to engage the grid or a backup generator; however, excessive charging during nighttime or morning hours may reduce the system's ability to absorb daytime PV surpluses, leading to curtailment or undesirable exports under unfavorable conditions. Further development has led to combined dispatch strategies with adaptive switching between these modes depending on the system state and expected demand, enabling cost reduction while maintaining a high RES share in the energy balance [5]. Nevertheless, a common drawback of rule-based strategies is their reactive nature: they are formed based on current measurements and only limitedly account for future changes in generation and tariffs, thereby reducing economic efficiency under variable electricity pricing [6].

In grid-connected operation, two main economic logics typically dominate HPSS exploitation: increasing the share of on-site generation in load coverage and reducing costs through controlled load shifting according to tariff structures. These approaches define different and sometimes conflicting control objectives [7]. The effectiveness of solar generation utilization is appropriately assessed through self-consumption and self-sufficiency indicators, reflecting the share of locally used PV energy in total generation and the share of load covered by on-site (including stored) generation, respectively. In a self-consumption-oriented mode, the ESS primarily performs a buffering function: it charges during PV surplus and discharges during solar generation deficits. The economic rationale lies in avoiding electricity purchases at retail tariffs for each additionally utilized kilowatt-hour of on-site generation. However, research results indicate that, given the high cost of ESS, an isolated focus on self-consumption may be characterized by an excessively long payback period in the absence of additional monetization mechanisms or cost compensation [8].

Another approach involves the use of multi-zone tariffs or dynamic pricing, where ESS control is aimed at cost minimization by charging during low-price periods and discharging during high-price hours to substitute expensive imports; if export is allowed, additional revenue may also be generated. According to certain studies, under specific conditions such tariff-oriented operation can significantly reduce the payback period of ESS investments, especially given the ongoing decline in capital expenditures [6,9]. However, it has also been shown that intensive use of tariff mechanisms may increase the total volume of bidirectional grid exchange in the long term, potentially intensifying peak power flows and conflicting with the objective of locally reducing the load on distribution infrastructure [10]. Moreover, combining tariff-oriented control with self-consumption maximization requires reserving part of the ESS capacity: excessive morning discharge aimed at savings or export may result in insufficient available capacity to absorb peak daytime PV generation. Therefore, HPSS dispatch requires a formalized balance of objectives through appropriate selection of objective functions and constraints.

A key factor limiting intensive ESS operation is the degradation of electrochemical elements, which accompanies each charge–discharge cycle and leads to gradual loss of usable capacity and increased internal resistance [4,11]. Ignoring degradation costs in optimization problems results in excessive cycling for marginal short-term gains, while the long-term consequence is accelerated depletion of ESS lifetime and increased replacement costs [12]. ESS wear is typically divided into calendar degradation, dependent on time, temperature, and average state of charge, and cycling degradation, determined by the number of cycles, depth of discharge, and current loading regimes. The literature commonly presents approaches integrating degradation into optimization models via generalized energy throughput indicators and the introduction of a specific "degradation cost," preserving linearity and computational tractability for dispatch problems. More detailed physicochemical models are also applied, providing higher accuracy in aging description; however, their nonlinearity significantly complicates long-horizon optimization and usually requires simplification or post-assessment use [12].

The limitations of reactive rule-based control strategies have stimulated a transition toward proactive approaches using solar generation and load forecasting. In such systems, forecasted PV output and demand values serve as inputs for optimization over a rolling planning horizon, ensuring adaptation to expected conditions and improved robustness against forecast errors [13]. One of the most widely used tools is model predictive control, where the optimization problem is solved for a specified time horizon, but only the first control action is implemented, followed by data updating and recalculation [14]. Forecast utilization allows, on the one hand, advance release of ESS capacity before expected daytime PV surpluses and, on the other hand, planned charging during low-tariff periods only to the extent necessary for peak-hour coverage, thereby reducing unnecessary losses and degradation.

Given the multidimensional nature of HPSS dispatch problems, characterized by multiple energy sources, time-varying tariffs, power conversion constraints, and ESS degradation processes, a significant portion of studies relies on mathematical optimization methods. To address forecast uncertainty, stochastic formulations are applied, while in cases of significant nonlinearity, metaheuristic methods capable of generating compromise solution sets are used. Nevertheless, publication analysis reveals fragmentation of approaches: some works focus primarily on self-consumption, others on tariff-oriented control, whereas the integration of local solar generation, tariff components, and ESS degradation within a unified, practically applicable linear model remains insufficiently covered. Certain comprehensive formulations minimizing degradation with high accuracy often require substantial computational resources, complicating their application in real dispatch systems of industrial facilities.

The objective of this study is to evaluate the impact of integrating photovoltaic generation and ESS on the operational performance of a power supply system. To this end, four operating scenarios are compared: grid-only power supply, power supply using only PV installations, a hybrid mode with ESS used exclusively for storing excess PV generation, and a mode with ESS charging during off-peak tariff periods, taking into account self-consumption and self-sufficiency indicators.

Mathematical Formulation of the Problem

An enterprise is considered whose power supply can be organized according to different scenarios: exclusively from the external grid; with the use of a photovoltaic (PV) installation; within a hybrid system including an energy storage system (ESS) used solely for storing excess solar generation; and within a hybrid system with generation forecasting and active tariff-based charging optimization. The formalization of these scenarios is carried out within a unified mathematical model by introducing appropriate structural and algorithmic constraints. It should be emphasized that, in this study, the dispatch problem is not formulated as a purely instantaneous real-time optimization based only on the current measured values of load, PV generation, and battery state of charge. Instead, the considered approach corresponds to short-term operational planning on a rolling horizon. At each decision step, forecasted values of load and PV generation, together with known tariff parameters, are used to determine the economically justified charging, discharging, import, and export schedule over a finite optimization horizon. After solving the optimization problem, only the first control action is implemented, and the procedure is repeated at the next time step using updated input data. Therefore, the objective function is written in an integral discrete form over the planning horizon, which is consistent with predictive dispatch rather than with a purely real-time control strategy.

Let the discrete time horizon of analysis be defined by the set $t \in \{1,2,\dots,T\}$ with a time step Δt. The known or forecasted quantities are the enterprise load L_t, PV generation PV_t, the electricity import tariff c_t^{imp}, and, if applicable, the export tariff c_t^{exp}. The control variables are the charging power P_t^{ch}, discharging power P_t^{dis}, grid import P_t^{imp}, and grid export P_t^{exp}.

The general power balance equation is given by

$$L_t = PV_t + P_t^{\mathrm{dis}} - P_t^{\mathrm{ch}} + P_t^{\mathrm{imp}} - P_t^{\mathrm{exp}}.$$

The ESS state-of-charge (SOC) dynamics are described by

$$SOC_{t+1} = SOC_t + \frac{\eta_{\mathrm{ch}} P_t^{\mathrm{ch}} \Delta t}{E_{\mathrm{nom}}} - \frac{P_t^{\mathrm{dis}} \Delta t}{\eta_{\mathrm{dis}} E_{\mathrm{nom}}},$$

subject to the constraints

$$SOC_{\mathrm{min}} \le SOC_t \le SOC_{\mathrm{max}},$$
$$0 \le P_t^{\mathrm{ch}} \le P_{\mathrm{max}}^{\mathrm{ch}}, \quad 0 \le P_t^{\mathrm{dis}} \le P_{\mathrm{max}}^{\mathrm{dis}}.$$

The economic objective of minimizing total electricity costs without accounting for battery degradation is defined as

$$J = \sum_{t=1}^{T} \left(c_t^{\mathrm{imp}} P_t^{\mathrm{imp}} - c_t^{\mathrm{exp}} P_t^{\mathrm{exp}} \right) \Delta t.$$

To account for battery degradation, a specific degradation cost is introduced:

$$c^{\mathrm{deg}} = \frac{C_{\mathrm{bat}}}{N_{\mathrm{cycle}} E_{\mathrm{nom}}},$$

and the corresponding degradation cost component is defined as

$$J_{\mathrm{deg}} = \sum_{t=1}^{T} c^{\mathrm{deg}} \left(P_t^{\mathrm{ch}} + P_t^{\mathrm{dis}} \right) \Delta t.$$

The generalized objective function then takes the form

$$J_{\mathrm{tot}} = J + J_{\mathrm{deg}}.$$

The performance indicators of solar generation utilization are defined as

$$SC = \frac{\sum_{t=1}^{T} P\,V_t^{\mathrm{com}}}{\sum_{t=1}^{T} P\,V_t},$$
$$SS = \frac{\sum_{t=1}^{T} P\,V_t^{\mathrm{com}}}{\sum_{t=1}^{T} L_t},$$

where PV_t^{com} denotes the portion of PV generation used to supply the load without export to the grid, including energy previously stored in the ESS and consumed within the enterprise.

In this study, the indicators SC and SS are not included directly in the optimization objective. Instead, they are used as post-optimization performance metrics for evaluating the quality of the obtained operating mode from the standpoint of local renewable energy utilization. The self-consumption indicator SC characterizes the share of generated PV energy that is consumed within the enterprise without being exported to the grid. The self-sufficiency indicator SS reflects the share of the total load supplied by local PV generation, including the part previously stored in the ESS and later consumed on-site. Their joint analysis together with the total operating cost makes it possible to distinguish between two different sources of efficiency improvement: an increase in the internal use of PV generation and a reduction in costs due to tariff-oriented temporal redistribution of electricity imports.

For the comparison to be methodologically consistent, all scenarios are evaluated for the same enterprise load profile and under the same external tariff conditions.

The reference scenario without local generation and storage is formalized as a particular case of the general model under the conditions $PV_t = 0$, $P_t^{\mathrm{ch}} = 0$, $P_t^{\mathrm{dis}} = 0$, and $P_t^{\mathrm{exp}} = 0$. In this case, the power balance reduces to $L_t = P_t^{\mathrm{imp}}$, and the objective function reflects only the cost of electricity purchased from the grid.

The scenario with PV generation but without ESS is described by setting $P_t^{\mathrm{ch}} = 0$ and $P_t^{\mathrm{dis}} = 0$. In this operating mode, PV generation is first used to cover the enterprise load, while any excess energy may either be exported to the grid or curtailed, depending on the adopted boundary conditions.

The hybrid buffer scenario with ESS is characterized by the prohibition of charging from the grid. Accordingly, the charging power is limited by the instantaneous PV surplus:

$$P_t^{\mathrm{ch}} \leq \max(0, PV_t - L_t).$$

In this case, the ESS performs the function of buffering excess PV generation in order to increase self-consumption and self-sufficiency, while tariff arbitrage is excluded by construction. Discharging is permitted only when the load exceeds current PV generation.

The predictive tariff-oriented scenario extends the previous case by allowing controlled charging of the ESS from the grid during low-tariff periods when this is economically justified and does not violate the battery constraints. In this case, the scheduling of ESS operation is performed using forecasted values of $\widehat{PV}_t$ and $\hat{L}_t$ over the rolling horizon. The expected daytime energy deficit may be estimated as

$$E^{\mathrm{def}} = \sum_{t \in \mathcal{T}_{\mathrm{day}}} \max\left(0, \hat{L}_t - \widehat{PV}_t\right) \Delta t,$$

and this quantity may be used to determine the target charging level before the beginning of the higher-tariff period. In contrast to the buffer mode, this scenario allows the ESS to perform not only renewable energy buffering but also tariff-based load shifting.

Thus, the proposed unified mathematical formulation makes it possible to represent, within a common framework, a reference grid-supplied case and three operating scenarios with fixed technical parameters of PV generation and ESS but different dispatch logic. The model is used to determine the operating schedule that minimizes the short-term operating cost on a rolling horizon, while the indicators SC and SS are used to evaluate the degree of local renewable energy utilization achieved by each scenario.

Simulation Results and Analysis

To ensure a consistent comparison, the simulations for all scenarios were carried out using the same hourly load data set, PV generation profiles, and tariff parameters. The installed PV capacity was kept unchanged across all scenarios involving photovoltaic generation. The simulation was performed for the aggregated load of two enterprises. For comparison, four scenarios were considered: the baseline case, a PV-only option without an ESS, a hybrid option where the ESS is used solely to store excess PV generation, and a hybrid option with predictive control that allows ESS charging during minimum-tariff hours. The evaluation was based on total electricity costs, import/export volumes, and the self-consumption (SC) and self-sufficiency (SS) indicators.

It should also be noted that the present study focuses on the operational comparison of dispatch strategies and operating configurations for fixed equipment parameters. Capital expenditures related to the installation of PV panels and ESS are not included in the optimization objective. Accordingly, the obtained results should be interpreted as an assessment of operating efficiency rather than as a full life-cycle investment appraisal. A comprehensive economic evaluation including capital costs, payback period, and net present value is considered a subject for further research.

Tables 1-2 summarize the results for the summer and winter periods. For the summer period, the transition from the baseline scenario to the PV-only option reduces costs to 48.97% of the baseline level, accompanied by an increase of SC to 45.40% and SS to 55.07%.

Adding an ESS operated in the mode of charging only from PV surplus leads to a further cost reduction to 36.15% of the baseline level and increases SC to 54.45% and SS to 66.05%. Compared to the “PV without ESS” option, grid imports decreased, indicating effective capture of part of the PV surplus and its subsequent use to supply the enterprise load. The mode with ESS charging during minimum-tariff hours in summer demonstrates practically identical values of SC and SS and similar energy balances, while total costs decrease slightly relative to the buffer mode. This is consistent with the fact that under a summer profile, where a significant share of demand is covered by PV and the ESS, the additional economic benefit from grid charging is limited.

Table 1 – Comparison of scenarios for the summer period

Scenario	**Costs, UAH**	**Costs, % of baseline**	**SC, %**	**SS, %**	**Import, kWh**	**Export, kWh**
Grid-only power supply	182 648 504	100.00	0.00	0.00	34 182 798.00	0.00
PV without ESS	89 433 877.51	48.97	45.40	55.07	15 356 732.84	22 638 045.07
PV and ESS (store PV surplus only)	66 034 712.87	36.15	54.45	66.05	11 605 255.04	18 483 960.86
PV and ESS (charging during minimum-tariff hours)	65 790 728.74	36.02	54.45	66.05	11 605 255.04	18 483 960.86

Table 2 – Comparison of scenarios for the winter period

Scenario	**Costs, UAH**	**Costs, % of baseline**	**SC, %**	**SS, %**	**Import, kWh**	**Export, kWh**
Grid-only power supply	211 993 984.40	100.00	0.00	0.00	34 182 798.00	0.00
PV without ESS	144 359 145.50	68.10	78.90	32.31	23 138 419.88	2 953 433.89
PV and ESS (store PV surplus only)	127 694 610.40	60.24	97.24	39.82	20 571 182.77	111 527.74
PV and ESS (charging during minimum-tariff hours)	123 506 264.70	58.26	97.24	39.82	20 571 182.77	111 527.74

For the winter period, baseline costs are higher and the effectiveness of PV without an ESS decreases: costs amount to 68.10% of the baseline level, while SS equals 32.31%. This corresponds to lower winter PV output and weaker alignment between generation and load profiles. At the same time, SC for the "PV without ESS" scenario increases to 78.90%, which is explained by relatively small PV surpluses: a large portion of generated energy is consumed immediately and export remains comparatively low. Integrating an ESS in buffer operation increases SC to 97.24% and SS to 39.82% and reduces costs to 60.24% of the baseline level. Particularly indicative is the sharp reduction of exports in the hybrid buffer scenario, which implies near-complete absorption of PV surpluses by the ESS and their use within the enterprise. The mode with ESS charging during minimum-tariff hours in winter provides an additional cost reduction to 58.26% of the baseline level, with unchanged SC and SS. Therefore, under winter conditions, the economic effect is mainly driven by the temporal redistribution of imports according to tariffs, whereas the contribution of PV to load coverage remains limited by the physical generation conditions.

A graphical interpretation of SC and SS for the three non-baseline scenarios is shown in Figs. 1-2. In summer, the ESS effect appears as a simultaneous increase in both SC and SS, corresponding to a higher share of on-site utilization of generated energy and reduced grid purchases. In winter, a characteristic situation is observed where SC approaches 100% in the hybrid scenarios while SS remains significantly lower, reflecting insufficient PV generation relative to the load demand.

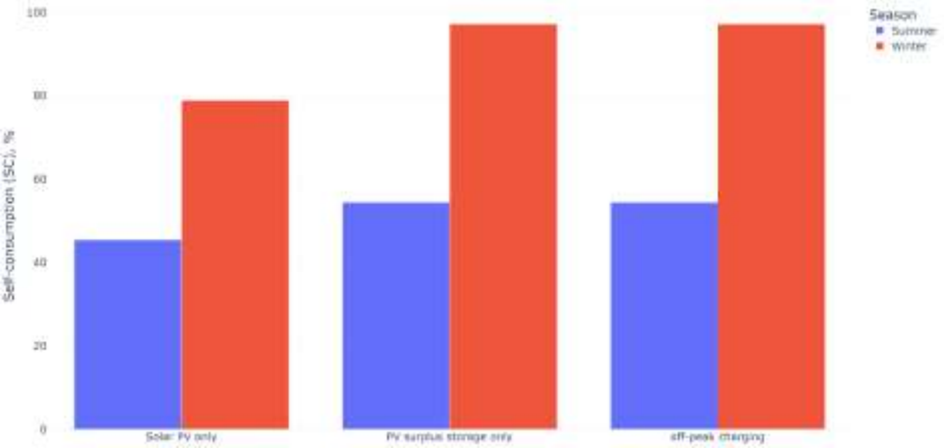

Figure 1 – Self-consumption indicator by scenario for the summer and winter periods

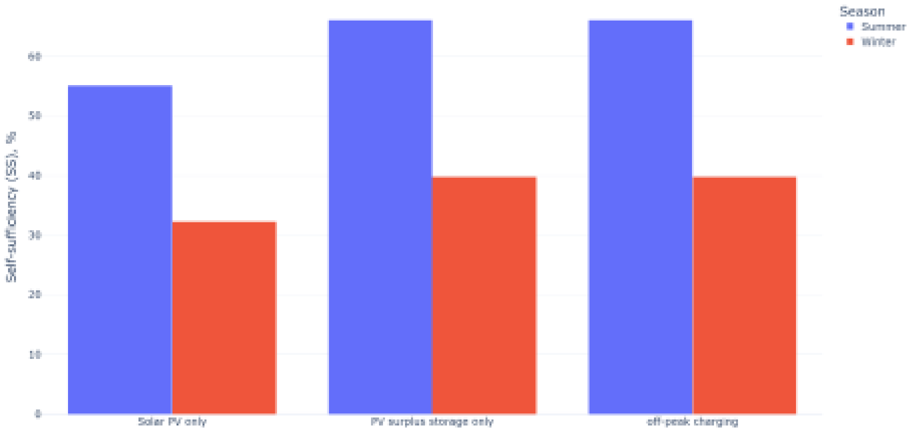

Figure 2 – Self-sufficiency indicator by scenario for the summer and winter periods

To illustrate the scenario with ESS charging during minimum-tariff hours, it is useful to consider representative daily profiles of the state of charge and charging/discharging power (Figs. 3).

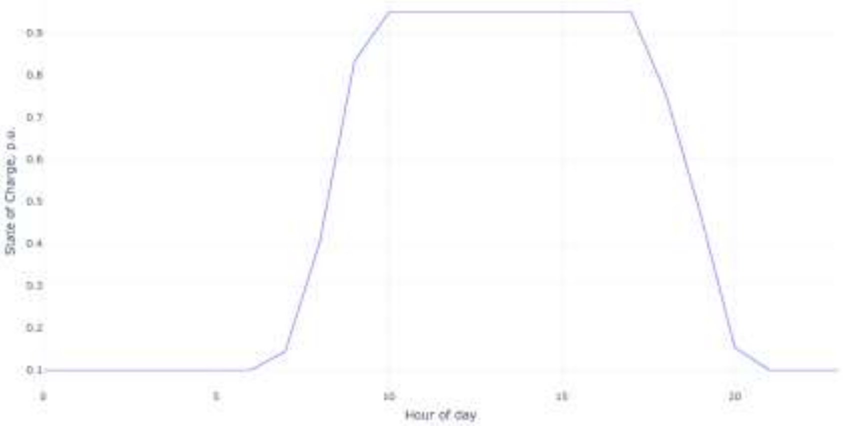

Figure 3 – Daily state-of-charge profile SOC (summer period with ESS charging during minimum-tariff hours)

These profiles show ESS charging in the morning hours, followed by maintaining a high SOC level during the daytime period and discharging in the evening interval that corresponds to higher tariffs. The absence of differences in SC and SS between the two hybrid scenarios is explained by the fact that the additional energy obtained from the grid during charging does not increase the locally consumed solar generation PV^{com}, but it reduces costs by replacing expensive imports during high-tariff hours.

Overall, the simulation results confirm that PV deployment is the determining factor for cost reduction in the summer period, whereas ESS integration substantially increases SC and SS and reduces import volumes by converting excess PV generation into a useful energy resource for on-site demand. In winter, the ESS ensures near-complete utilization of PV surpluses and a moderate increase in SS, while the additional economic effect is achieved through tariff-driven import redistribution enabled by charging during minimum-tariff hours.

Conclusions

This work provides a comprehensive analysis of the efficiency of hybrid power supply systems for enterprises with photovoltaic generation and energy storage systems under different dispatch strategies. Based on hourly simulations that account for seasonal load and generation profiles as well as multi-zone tariffs, the impact of integrating PV installations and ESS on the economic performance of the system and on the self-consumption and self-sufficiency indicators was investigated.

The results confirm that PV deployment is the key driver for reducing electricity costs, particularly in the summer period characterized by high generation output. At the same time, the use of ESS significantly improves the utilization of generated solar energy by storing surplus energy and subsequently using it to supply on-site demand. In summer, this is reflected in a simultaneous increase of both SC and SS and a reduction of grid import volumes, whereas in winter the ESS ensures near-complete internal utilization of PV generation, although the self-sufficiency level remains limited by physical generation shortages.

It was additionally found that the forecast-oriented strategy allowing ESS charging during minimum-tariff hours improves the economic performance of the hybrid system without changing SC and SS. This indicates that efficiency improvements in hybrid systems are achieved not only by increasing the share of renewable generation, but also through optimizing ESS operating modes with consideration of time-differentiated electricity prices and battery degradation costs.

At the same time, the results should be interpreted within the scope of the adopted research design. The paper compares operating scenarios for fixed PV and ESS parameters and focuses on operating cost minimization together with post-optimization assessment using the self-consumption and self-sufficiency indicators. Therefore, the obtained conclusions characterize the operational effectiveness of different dispatch strategies rather than the full investment attractiveness of alternative system configurations over the entire life cycle. These conclusions are also relevant to the conditions of Ukrainian enterprises, where the economic effect of ESS may be determined not only by tariff differentiation, but also by increasing self-consumption of PV generation and reducing grid dependence.

Further research should focus on deepening the analysis by accounting for uncertainty in generation and load forecasts, refining ESS degradation models with consideration of operational factors, and solving the problem of optimal sizing of PV installed capacity and ESS energy capacity within a multi-criteria optimization framework that includes techno-economic and network constraints.

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ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ГІБРИДНИХ СИСТЕМ ЕЛЕКТРОПОСТАЧАННЯ ЗА РАХУНОК ЗАСТОСУВАННЯ УСТАНОВОК ЗБЕРІГАННЯ ЕЛЕКТРОЕНЕРГІЇ

У роботі проаналізовано підвищення ефективності гібридних систем електропостачання підприємств шляхом інтеграції фотоелектричної генерації та систем накопичення енергії з різними алгоритмами диспетчерського керування. Розглянуто чотири сценарії роботи: електропостачання тільки від зовнішньої мережі, використання лише фотоелектричних установок, гібридний режим із накопиченням надлишкової генерації в системі накопичення енергії та режим із прогнозно-орієнтованим заряджанням установок зберігання електроенергії. Моделювання виконано з погодинною дискретизацією з урахуванням сезонних графіків навантаження, сонячної генерації та вартості деградації акумуляторної батареї. Ефективність оцінювалася за сумарними витратами на електроенергію, обсягами імпорту та експорту, а також за показниками власного споживання та самозабезпечення. Отримані результати показують, що інтеграція систем накопичення енергії істотно підвищує рівень використання локальної генерації та зменшує залежність від мережі, тоді як застосування прогнозно-орієнтованих алгоритмів керування забезпечує додатковий економічний ефект без зміни структури використання сонячної енергії. Водночас запропонований підхід є придатним для умов електропостачання підприємств в Україні, де ефект від використання накопичувачів може додатково визначатися підвищенням рівня локального використання відновлюваної генерації та зменшенням залежності від зовнішнього електропостачання.

Ключові слова: *гібридна система електропостачання, фотоелектрична генерація, установка зберігання енергії, диспетчеризація, самоспоживання, самозабезпеченість.*

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