

Research Article

The Potential Role of PV Solar Power System to Improve the Integration of Electric Energy Storage System

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Integration technique is becoming effective due to the world's largest power requirement, which has imposed a considerable need for various techniques by which electricity can be generated or integrated, as well as the assumption that integrating solar energy into nonrenewable source materials is essential to minimize the relative to nonresource consumption and thus reduces fossil fuel consumption. Photovoltaic (PV) systems are at the forefront of this transformation, harnessing the sun's renewable electricity and converting this from DC to AC. Controlling the power grid utilizes power system photovoltaic energy production and the many ramifications of grid-scale PV energy module integration into energy systems. To completely integrate photovoltaic (PV) processes into a network, cost-effective and efficient technologies of energy storage must be used in conjunction with smart energy management systems. Electrical energy storage system (EES) could have been used to improve a system's stability and the performance, to recent technology improvements and quick efficiency improvements. This research provides an understanding of EES for the photovoltaic system as well as a complete evaluation of the developing penetration level of PV. As the worldwide photovoltaic solar market is expanding, growing onsite use of PV-generated energy would become increasingly critical to ensure the stability of the grid. This research study was the first one to provide such a comprehensive overview of all forms of energy storage devices which can be used in conjunction with PV, including both thermal and electrical energy storage systems. Finally, a simulation of optimization planning is executed. The result reveals that lowering peak loads and lowering electricity usage lowers the price of electricity.

1. Introduction

Solar-grid connection is a system that allows large amounts of photovoltaic (PV) power to be integrated into the public

power system. This is a crucial requirement because integrating standardized photovoltaic systems into grids optimizes increase energy balancing, enhances photovoltaic system economy, lowers operating costs, and adds benefits

to customers and utilities [1]. As there is an increasing desire for alternative renewable power to replace fossil fuels, solar-grid interconnection has become a regular practice in several nations throughout the world. Recent global attempts to reduce energy usage and investigate alternate energy options have been prompted by the shortage of fossil fuels and their detrimental environmental impact [2]. Considering that the construction sector consumes roughly 20–40% of the amount of energy in advanced economies, renewable power technologies represent a potential alternative energy source for addressing the energy problem and issues affecting architecture demand. Solar energy is more suitable as a power source of supply for buildings with constrained installation area, active vibration requirements, and an unpleasant atmospheric condition in an urban setting, so it is important to incorporate structural elements [3]. However, because solar energy is often inconsistent and unexpected and thus does not always match building needs, power storage solutions are required to ensure a steady and reliable electricity supply [4]. The integrated renewable energy storage unit can regulate the speed of the distribution network for on-grid photovoltaic systems, as well as to adapt the solar energy flow to match the structure growth and increase power authority. As a result, it is critical to look into integrating different electrical energy storage (EES) techniques using photovoltaic (PV) devices for an efficient construction power source.

There are some other basic equilibrium solutions. Electric energy storage systems (EES) can also be utilized to save the energy when there is an excess to utilize it when there is a shortage. The hydroelectric capabilities of specific locations can also be used to balance other regions by linking separate grids [5]. Another sustainable option is bioenergy, which has the advantage of lengthy storability as well as the technological ability to compensate for some of the fluctuations in solar power output. Concentrated solar power (CSP) is a decent selection in some places with strong direct sunrays; it is not a feasible option in others. Solar photovoltaic (PV) generating capacity has expanded substantially over the last century as one of a transition away from fossil fuels more toward reliable, clean, effective, and sustainable energy. To store surplus PV electricity produced for subsequent use when needed, PV technologies with energy production are required [6]. Energy production can serve to promote systems to survive demand spikes and keep transmission and a grid distribution running smoothly. In terms of short storage durations, this can be useful for leveling out transient voltage peaks and irregularities.

As illustrated in Figure 1, the most suitable energy storage media for PV-produced energy is determined by the planned end-use. Global energy production exceeds the world energy need by a large margin. However, owing to the cyclical and unpredictable characteristics of solar energy, integrating it into the power system is difficult. The amount of solar electricity generated is related to the amount of solar irradiation. This means that to avoid swings, dispatchable generators, such as coal-fired or gas-fired power plants, must alter their power production frequently. As a result, calculating a suitable system reserve for stable and safe operations becomes difficult. Increased system adaptability must

become a goal for policy and decision-makers if photovoltaic (PV) technologies acquire a bigger percentage of power generation, i.e., as adoption rises [7]. Electrical energy storage (EES) may enhance and give functions for power systems; therefore, it will be widely used. To improve the integration of electric energy storage systems (EES), stored energy is expected to be a critical element of the smart grid [8]. There is interest in developing enhanced operational techniques for evaluating the integrity and safe functioning of renewable electricity networks with high integration.

2. Related Work

Energy storage is becoming a major player in energy storage systems. The goal of this article is to conduct researches on integrating battery-based energy storing with such a hybrid grid-connected wind-solar electricity system to effectively dispatch wind output by adding peak shaving and ramping speed preventive. The sizing technique is adjusted using a bat optimizing method to reduce a system's development losses from power outages and wind restriction. The integrated system is next put through its paces with a battery control mechanism that protects the battery from being overcharged or discharged. Five main kinds of battery storage are explored and analyzed in the study. They were developed and analyzed depending on techno-economic and ecological indicators in the situation of the Indian electricity markets. Simulation on a planned system of wind-photovoltaic in a wind location in South India supports the battery's techno-economic evaluation. An experimental test is carried out by calculating the cost of emission reductions [9]. An electricity user as being subjected to time-of-use price and a request price uses real-coded evolutionary algorithms to arrange the charging of an energy storage system (ESS) that is utilized in conjunction with sustainable power. Analyses focused on average residential customer demand and production profiles demonstrate that an ESS planned by the method can cut electricity expenditures by about 17% compared to a network without the need for an ESS and by 8% relative to such a scheduling strategy based on average power [10].

The research state of architecture and controlling approach of energy storage grid-connected systems is evaluated in this research, as well as a cascade power electronic transformer (CPET) with a separate Dc converter is considered to improve the operational conditions of a recycled battery. The current supplied isolated bilateral DC-DC converter and a cascaded H-bridge (CHB) working principles are investigated, and a decoupled control method is devised. The repurposed battery energy storage (RBES) grid-connected device is constructed in this study using a centralized control technique based on CPET, which has 3 levels: state of charge (SOC), energy, and power. The resource layer reacts to voltage and frequency management directives, the power completely covered grid-connected electricity, and records voltage level, as well as the SOC layer, corresponds between battery charged states. A three-phase grid-connected model can be tested with a capacity of 3 MVA/12 kV was built, as well as a single-phase system

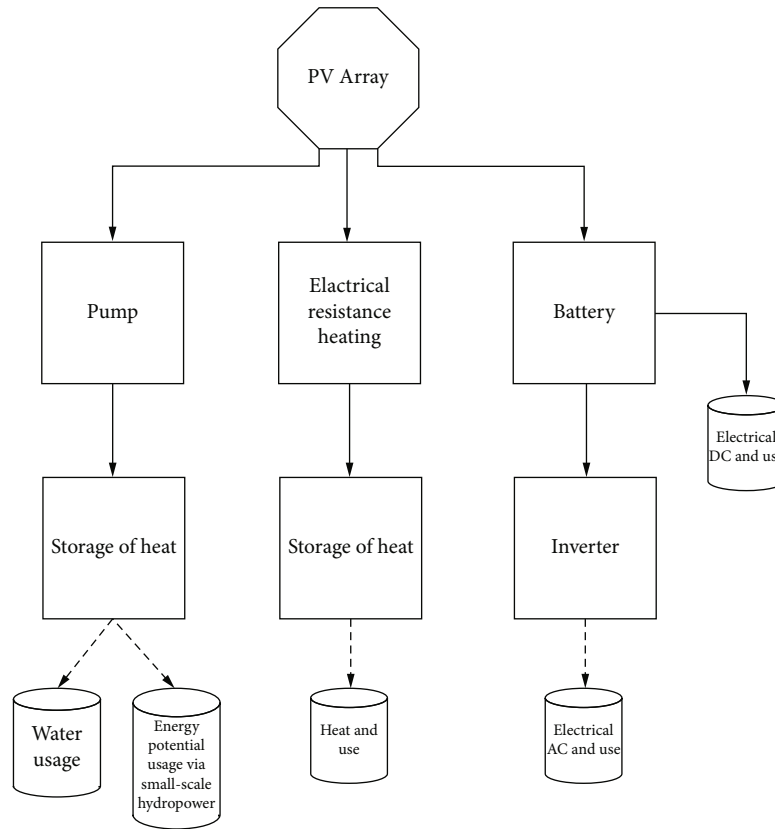


FIGURE 1: Photovoltaic energy storage system.

experimental platform with a capacity of 1 kW. The simulations and practical data can be used to confirm that the mathematical model is true and that the proposed controller is feasible [11].

This research incorporates a hybrid storage system of super capacitor into a wind-solar hybrid energy harvesting system, allowing the system's power storage space and power output to be significantly increased. This study's approach combines a decentralized power generation system with a hybrid energy system while increasing output power in phases utilizing a static voltage regulation system and a process of developing a dual-mode control scheme. Simultaneously, using MATLAB/Simulink technology, the highest efficiency model of a wind-solar combination power generation is constructed. Simulation is used to determine the microgrid's power output to the wind-photovoltaic mixed power generating system, as well as the optimization method for each system element. To improve the wind-solar hybrid power generating system, this study primarily utilizes the static power factor correction system as well as the conductance-fuzzy dual-mode control scheme. The capability and rationale of the ideal system layout are verified using the MATLAB simulation software [12].

This work reveals that a single energy source typically energizes the entire system and frequently leads to failures. The battery capacity lifetime and excessive regular expense are the primary concerns. Because of its complexity and expertise, the system has been undersized or oversized on occasion. Solar cell restrictions must be optimized. The com-

bination of lead-acid batteries and super capacitors reduces the stress on the batteries and extends their life. To handle the quick input fluctuations across the solar module, an ANN model is used. As a case study, the research uses models of the Nsukka seismic node to better analyze the process. Identifying of PV system factors at a typical remote seismic device via energy transmitter and storage designing, optimal dimensioning of photovoltaic modules as well as a lead-acid charger, and, finally, a combination of energy storage devices to facilitate the energy management system to maximize the accessible atmospheric illuminance are all major contributors of the research. The results reveal that the neural network provided an order to create good switching frequency all across converters and fewer complications, while the capacitors supplemented the lead-acid battery and provided overall effectiveness of roughly 75% [13].

3. Materials and Methods

3.1. Electrical Energy Storage (EES) Technology Global Development for PV Systems. Figure 2 depicts the study's general framework. This research examines the current state of hybrid PV-EES systems for structure power sources, as well as the scope of research and process optimization. To encourage future deployment of PV-EES technology in structures, suitable combination PV-EES systems for building's power source and possible research requirements are detailed. Electrical energy storage (EES) is the conversion of electrical energy in to another condition that can be

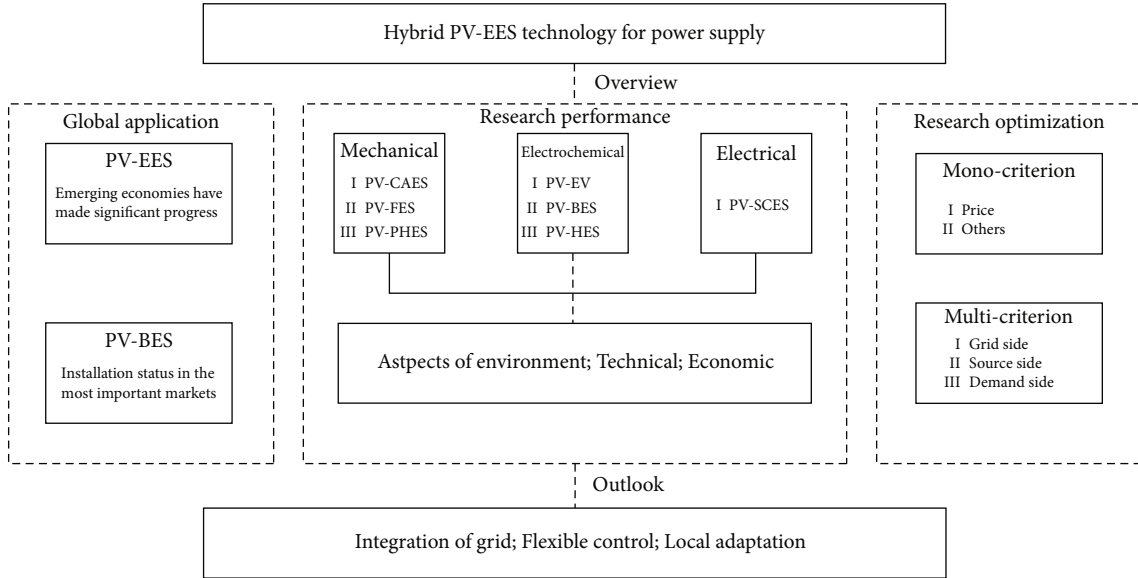


FIGURE 2: The hybrid of PV-EES technologies' main objective for grid supply.

maintained and transferred back to electricity when required. Photovoltaic systems combined with renewable power can increase the amount of self-consumed PV electricity [14]. The extra PV electricity generated most of the day is retained in such a battery system and utilized at night. Residents with PV-battery systems can lower the amount of electricity they require from the grid and enhance themselves. PV-battery solutions thereby minimize residential customers' reliance on the grid connection while also lowering carbon pollution.

3.2. Using EES for PV. EES is a method which allows energy to generate at a period when prices are low and generating costs are low, or from distributed generation to use when prices increase and production costs are high when another production is unavailable. Such a base load-producing unit can charge storage in the early morning and late at night. this stored energy is being utilized to balance demand during peak hours, which occur about 6 p.m. Furthermore, by utilizing the available resources between 6:00 a.m. and 6:00 p.m., energy storage preserves frequency and voltage.

Chemical, mechanical, and thermal storages are only a few of the different types of EES. Many of these basic groups have their own set of economic and efficiency considerations. Photovoltaic systems can provide additional social benefits, such as reduced carbon-emissions because PV solar creates power from a solar energy which could have been used to produce electricity from fossil fuels [15]. Although the advantages flow to society as a whole, emission reduction advantages are a major inducement for many who install PV systems. PV-battery systems can also provide grid-level advantages, including enhancing the overall effectiveness of the electrical grid and lowering the cost of the system.

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- (i) To compensate for the use of more costly generators
- (ii) Minimize distribution and transmission network congestion
- (iii) Control the flow of electricity
- (iv) Regulate voltage variations in the nearby area
- (v) Upgrades to transmission and distribution systems can be avoided or postponed

When advantageous regulations, such as tax benefits, specific rate designs, net metering, and feed-in prices are introduced, they can lower the cost of electricity.

4. Proposed Methodology

4.1. EES Generic Model. There are two types of power system analysis and preparing:

- (i) Static analysis and preparing
- (ii) Dynamic analysis and preparing

The static computations do not employ timing [16]. Only the maximum consumption is being used to size the electronic systems and electricity in terms of balancing power generation over a one-hour or one-day period (24 hr). EES models of varying quality are required to offer computations in the power network strategic planning. The quality and features of the selected EES models for such computation should approximate the average representations of the power system

network, such as transformers and generators. Dynamic models of electric equipment are required for dynamic calculations; these approaches primarily use ordinary differential equations to describe the characteristics of items.

For extensive EES modeling (e.g., inverter dimensioning), more appropriate EES projections depend on, for example, similar networks that are sometimes necessary [16]. The EES methods for dynamic computations will not be treated in this paper because it has already been covered in greater depth in other works. The simulations can be modified dependent on the computation timescale, and then, the calculation includes a very brief time; the constant behavior of the EES model's technology modeling could be considered in a critical condition.

Parameterization of statistically specified models is based on data measured and physical features of the devices. The reliability of the models should be improved to enable extensive evaluations of major channels that take into account the primary parameters and performance of different devices (including EES) without unnecessarily increasing computation time. In terms of modeling needs, the EES can be incorporated into the power system computation as a hybrid generation/load component. If the storage solution has one or more generation devices (generators), they should be fully taken into account.

To meet the above-described requirements, an EES model's section usually should include at least three edges from Figure 3. The initial, the primary surface, is made up of the physical model, which is mostly represented by theoretical descriptions and contains the EES model's central point. This model's physical surface (PhS) is then blended into its specific surroundings, such as the load's electrical and thermal demands, and additional interactions and requirements on the structural model are provided, especially when considering system control simulation. Table 1 highlights the modeling needs for the EES-PhS, taking into account various forms of storage and modeling implementation methods.

4.2. Development of EESS's Perspective Group. An experienced assessment of the vast variety of technically accessible electrical energy storage system (EES) techniques was conducted to evaluate then associate the systems with a projected data of techno-economic till 2050. Lithium, nickel, and lead are storage-dependent in the short term; redox flow, pump hydro, and high-temperature memory devices are concentrated in the middle period. To obtain data input for such following method, every technique was subjected to a thorough reading of important techno-economic facts.

Simultaneously, the remaining peak demand has to be assessed to increase a total capacity of EESS and the power requirements based on the situation. The analytical hierarchical process (AHP) was used to determine a percentage from each technology depend on a techno-economic information and an EESS capability then the power to generate a network of electrical power storage areas [17]. The goal of this research was to find the best way to use sustainable power. As a result, for low- to midstorage, the capacity of electrical energy storage devices was constructed under the

highest negative remaining load of CLASSIC situations, correspondingly. Short-term storage requirements are for negative residual pressures that happen in just a day, whereas midterm storage requirements are for negative residual workloads that occur between a few days and 3 days.

The analytic-hierarchy-process (AHP) utilized in a domain of choice making was modified such a state to construct the fleet of a EESS systems through specifying a contribution of every knowledge for an EESS short- and midterm. The most important component of this procedure is the pairwise assessment of the classes and measures to find the best choice for two pathway situations. The AHP is used to identify a share of every technology inside the short- and midterm cluster, rather than analyzing multiple EESS solutions. EESS grouped essential criteria for describing the technology into three categories: environmental consequences, technical factors, and economic implications. Relevant criteria, as well as their weighting influence of importance, were already discovered within these clusters. The weighting variables for the various criteria are determined mostly through pairwise comparisons of the groups and the criterion within every category. The most important characteristics, according to this strategy, are cycle capability, effectiveness, and prices.

4.3. ESS for Energy Management. By charge/discharge, ESS can lower electricity prices and minimize peak load. As a result, the cost of electricity can be decreased. When run with optimal output scheduling, ESS could be more dynamic in response to peak management than to the solar system load, resulting in significant savings. The demand cost and the cost of energy are two types of electricity costs [18]. The method of minimizing energy usage to identify demand cost and also the method of minimizing power consumption to estimate electricity costs are both organized methodically in this research. The energy management optimization technique employing the ESS is depicted in Figure 4 as flow chart. Phase 1 and Phase 2 of the algorithm are separated. Phase 1 involves power management to reduce peak capacity. Phase 2 is designed to perform energy management to reduce energy costs while not reaching the peak demand set in Phase 1.

Stage 1 involves using the ESS to schedule peak load decreases based on expected monthly data collected. Similarly, the peak load (as determined by ESS) is associated regularly to modify the peak load which defines the monthly consumption cost [19]. When the peak demand that defines a monthly request cost is produced in monthly report, the ESS output is computed based on the peak eliminating unnecessary planning results. The optimal solution and constraint for Stage 1 are as follows:

$$\text{Min}\{\rho_d \times L_{\text{peak}}\}, \quad (1)$$

$$-L_{ch,\max} \times x(t) \leq L_{\text{ESS}(t)} \leq L_{dch,\max} \times y(t), \quad (2)$$

$$a(t) + b(t) \leq 1, \quad (3)$$

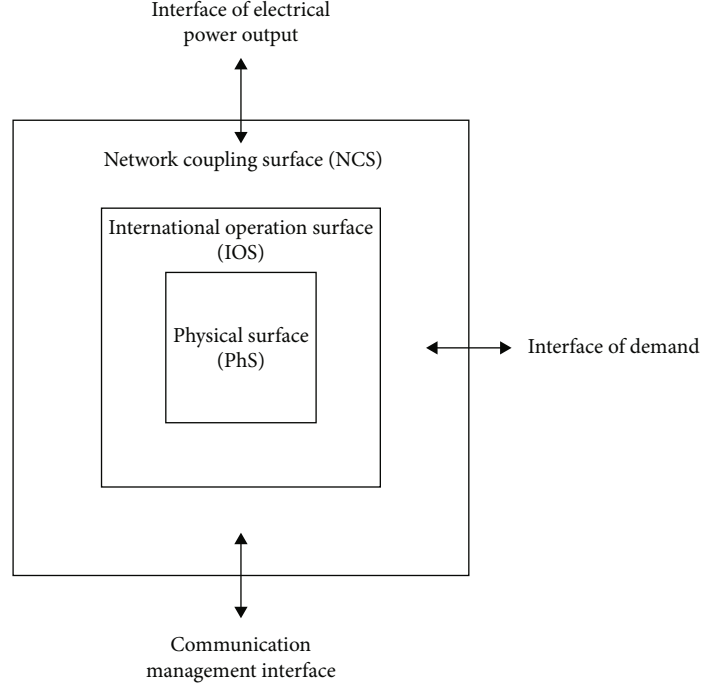


FIGURE 3: Generic model of ESS.

TABLE 1: EES physical surface modeling for planning of power network.

Requirement of model	Kind of storage	Used model
Model of static	Independent of storage type, a generic model is used	Model of a reservoir depending on the type of storage, parameters are set
Model of dynamic	Batteries, flywheels, CAES, PHS, storage medium H_2	Advanced model of AC generator

$$\text{SOC}(t) = \text{SOC}(t-1) - (b(t) \times L_{\text{ESS}}(t) \times \eta_d^{-1} + a(t) \times L_{\text{ESS}}(t) \times \eta_c), \quad (4)$$

$$\text{SOC}_{\text{lb}} \leq \text{SOC} \leq \text{SOC}_{\text{ub}}, \quad (5)$$

$$\text{SOC}_{\text{last}} = \text{SOC}_{\text{first}}, \quad (6)$$

$$\text{Load}(t) - L_{\text{ESS}}(t) \leq L_{\text{peak}}. \quad (7)$$

A functional form, Equation (1) serves as the basic rate. To reduce peak capacity, ESS power management is used. The price per kW of the demanding cost is denoted by d and L_{peak} . Equation (2) is a power restriction for charge/discharge. The discharge energy has a positive number whereas the charging energy is negative. The ESS charging power rating, power of ESS, and ESS discharging power rating are denoted by $L_{\text{ch,max}}$, L_{ESS} , and $L_{\text{dch,max}}$, respectively. Then, one of the charge-discharge modes can function at any given time, according to Equation (3). Furthermore, the ESS charging and discharging states are denoted by a and b , accordingly. Both parameters have binary numbers. The state of charge (SOC) for each cycle of operation is calculated using Equation (4). The ESS charging and discharging efficiency are denoted by d and c , respectively. The operational range of the ESS's SOC is limited by Equation (5),

and the ultimate SOC is equivalent to the beginning SOC, as displayed in Equation (6). The lower and upper boundaries of the SOC are denoted by SOC_{lb} and SOC_{ub} correspondingly. L_{peak} has the greatest value among the discrepancies among the load as well as the ESS power, as shown by Equation (7).

Phase 2 adds the restriction that uses this number after determining the peak capacity which defines the monthly consumption cost in Phase 1. The ESS accomplishes power planning using simply the price of electricity in the goal functional, ignoring the demand cost. The following are the goal function and extra constraint requirement in Phase 2 that minimizes the cost of energy in equation (8).

$$\text{Min} \left\{ \sum_{t=1}^{96} (\rho_e(t) \times 0.25 \times (\text{Load}(t) - L_{\text{ESS}}(t))) \right\}, \quad (8)$$

$$L_{\text{peak}} \leq L_{\text{peak,limit}}. \quad (9)$$

Considering the cost of electricity, the ESS executes optimization planning to fill at a minimum price of electricity and release at a higher price of electricity, thus according to Equation (8). The energy price is denoted by $\rho_e(t)$. Equation (9) makes the peak demand, which regulates the

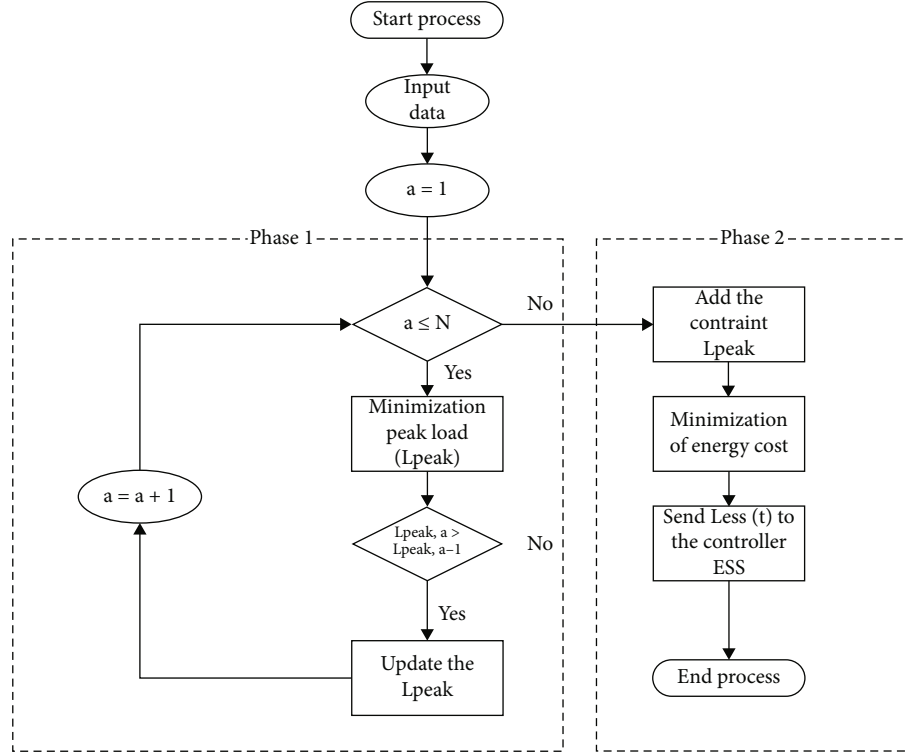


FIGURE 4: Flowchart of ESS optimization algorithm.

monthly consumption cost, a restriction, and prevents the emergence of original peak usage as a result of the ESS being overcharged based on the power price. $L_{\text{peak,limit}}$ denotes a maximum load limit. The peak-reduction method preferably schedules the day that the peak load happens monthly in Phase 1, then reschedules it to Phase 2.

4.4. Development of an Optimization Method for Fleet Operation Scheduling. The numerical optimization technique created from generic optimization model for energy storage that would be a mixed-integer, linear programming model for a such techno-economic evaluation of a EESS applications, used the generated data from three different previously stated processes. The updated model was used to evaluate the use of various power production technologies in various scenarios, including fossil power stations, adaptable bioenergy facilities, and short-term and midterm EESS. A “reserve” power station (reliant on rapidly steam turbines) was also installed to ensure remaining load coverage within every time interval [19]. The optimization’s objective function was to reduce the greenhouse gas emissions as much as possible. Furthermore, a rolling horizon has been used to limit precise vision to two days. On primary day, findings are recorded; the second day was used as a connection to avoid the electrical power storage being depleted after the day, which might contribute to a localized rather than global optimum. The outcomes of this end of the process are utilized to investigate the possibilities and interactions of technological developments for each 12 situations.

The goal of reducing greenhouse gas emissions is selected as an optimization problem since it directly corre-

lates with the overarching goal of producing as much electricity as possible from renewable sources. The equation contains the definition of the goal function (10). Together within rolling horizons, the number of emissions is estimated by adding the pollutants of every plant fossil-fueled for every time step t in each run optimization t . In addition, a cost element for gas-fueled power plants and reserve power plants has been implemented. The component is used to respect individual plants’ economic merit ranking, which is determined by their marginal cost of production on the spot price. As a result, the optimization problem prioritizes renewable power feed-ins that will be retained during one surplus condition or flexible biofuel plant feed-ins. Fossil-fueled power stations were now turned on if zero emission-free energy must be generated and delivered.

$$\min \text{CO}_2 = \sum_{T=1}^{365} \sum_{t=1}^n (\text{CO}_{2,\text{hardcoal}}(t) + 5 \cdot \text{CO}_{2,\text{gas}}(t) + 100 \cdot \text{CO}_{2,\text{reserve}}(t)). \quad (10)$$

Positive remaining load must be supplied for each time interval t , according to every supposed to ensure for assuring the security of supply and grid stability. The residual negative residual stress, on the other hand, is permitted. The left-over negative residual demand, i.e., excess electricity output, is believed to be employed in cross-sectoral equipment [20]. Power-to-heat and power-to-gas appliances are two examples of cross-sectoral devices, although there are several other alternatives. A further constraint ensures that adaptable biomass fuels can provide energy during the year. The

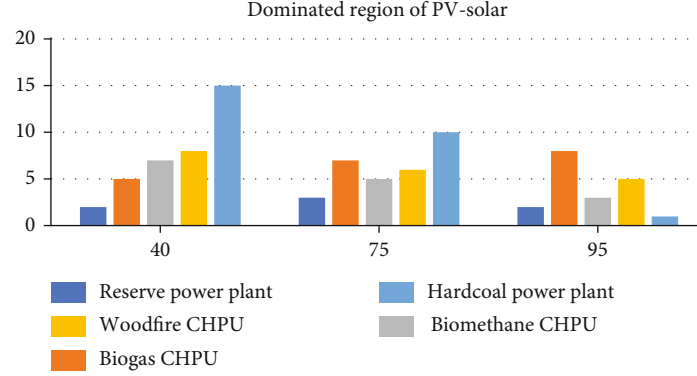


FIGURE 5: Coverage of the fleet's low residual demand by various facilities or EESS.

TABLE 2: After addressing the residual load, the remaining extra energy and power.

Region	Share of renewables	Excess of annual energy	Excess of maximum power
Dominated region of PV solar	40%	0	0.2
	75%	0.5	9.6
	95%	4.8	17.3

estimated annual quantity of biomass substrates was subdivided in equivalent to a quantity of positive residual demand throughout each optimization run T for this purpose. Several production process restrictions, such as power rating and capability, capability for part-load operations, rates of receivable ramp, rate of self-discharge, restricted number of attempts each day, the minimum downtime, and less running duration, were also applied for improvement.

5. Result and Discussion

The covering of leftover residual load by various plants or EESS is first demonstrated, and the monitoring impacts are explained. Following that, several key figures are related to the operation of the various plants, and EESS is presented. Finally, the features of leftover excess energy and power are discussed, and EESS optimization technique is also performed. In this section, Figure 5 demonstrates how the interactive activity power stations or EESS handle the remaining positive leftover demand of modeling regions, i.e., the capacity following feed-in renewable generation and must-run power plants. From 2030 to 2050, the percentage of CO₂-free generating electricity for both areas rises. In the solar zone, EESS shifts a greater quantity of renewable power over a period than those in the solar region. This could be for one of two main reasons: On the one side, likely, EESS does not quite fit the leftover positive leftover load's characteristic pattern. The amount of feed-in for the various bioenergy kinds of plants reflects the fraction of power rating. Furthermore, despite the penalty component in the optimization problem favoring coal facilities, there is a zero-electricity formed by a coal power station in the solar zone in 2050. The slower scaling behavior of coal power plants compared to gas-steam power plants helps explain this occurrence. Alternatively, the coal-fired power plant's long minimum power duration or long minimum suspension time could

be the origin of this phenomenon. It is also feasible that both factors play a role in the occurrence.

5.1. Excess Power and Energy. Table 2 shows the remaining excess power and energy after addressing the residual demand, while the maximum extra electricity in the solar-dominated region is higher. Contributing to the increase can account for both. The solar-dominated region has a greater annual excess energy due to the block-like occurrences of extra electricity during strong solar phases. EESS can only retain and period a limited portion of this extra wind energy in the short and medium run. When the EESS reaches capacity, the residual extra energy can only be utilized in cross-sectoral applications.

5.2. EESS Optimization. The EESS optimization algorithm's implementation and simulation. After modeling all of the periods using stage 1's technique, it was determined that maximum stress occurs. The EESS has a rated power of 2 MW and maximum storage of 2 MWh. Both the charge-discharge efficiency are adjusted to 90%. The initial and ultimate SOC are both fixed to 50%, with the SOC control parameter being set to 10% to 90%. Table 3 shows the possibilities for the EESS simulation. The purpose of setting the situation is indicated below so it can present all of the possible outcomes.

5.2.1. Case 1. Case 1's peak demand (with ESS) happens. As a result, phase 1 planning is used to reduce peak load (with ESS). Then, the SOC is set to the highest benefit well before the peak period, and the discharge is sustained from 2:00 p.m. to 6:00 p.m. since peak usage decrease is the major goal. The ESS reduces 479.4 kW at the initial peak demand, as shown in Figure 6. The peak demand decrease is not significant because the original load distribution is the level just at the peak. Table 4 summarizes the findings of case 1, as

TABLE 3: Simulation of state EESS.

State	EESS configuration data	Characteristic
Case 1	2 MW/2 MWh	Occurs on peak demand (with EESS)
Case 2	Initial SOC-50%	Case 2 occurs on peak demand (without EESS)
	Charge/discharge	Case 1 peak demand
Case 3	Efficiency-90%	Case 3 (without EESS) less than peak demand
		Case 1 (with EESS) peak demand

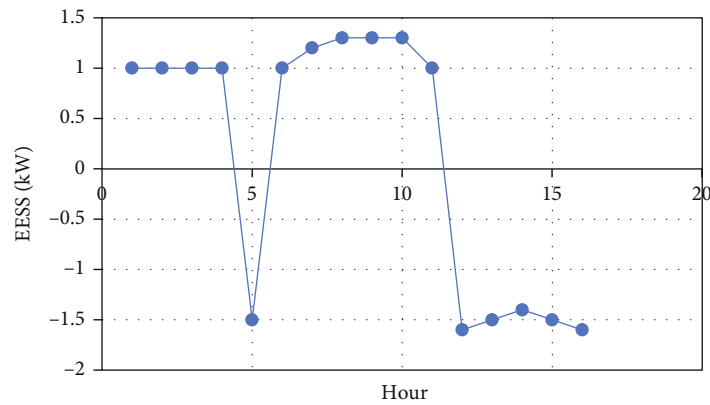


FIGURE 6: Power of EESS.

TABLE 4: Case summary of case 1.

State	Original peak demand	New peak demand (with EESS)	Reduction of demand cost	Reduction of regular energy cost
Case 1	5800.3 (kW)	5430.7 (kW)	3096.8 (\$)	137.6 (\$)

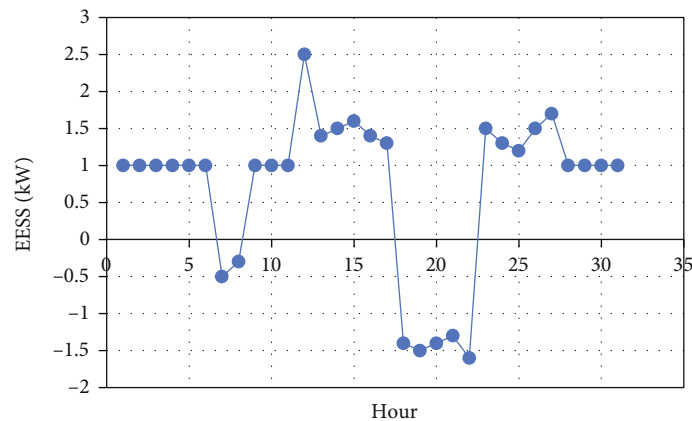


FIGURE 7: Power of EESS.

well as the peak demand that defines that the demand price is set at 5420.8 kW.

5.2.2. *Case 2.* Phase 1 is assigned to phase 2 of the flowchart; then, it is not the maximum load that defines the request cost through to the planning of minimizing the peak demand. The goal of case 2's simulations is to verify the

EESS's power planning when maximum stress reaches the peak demand which influences demand price. Because consumption cost is not incorporated in the optimization problem in Figure 7, discharge is done when the power price is too high to save energy. As a result of the low price of electricity, the EESS is compensated between 12:00 and 1:00 p.m. However, due to the peak demand restriction that

TABLE 5: Case 2 summary.

State	Original peak demand	New peak demand (with EESS)	Reduction of regular energy cost
Case 2	5615.2 (kW)	5420.7 (kW)	150.8 (\$)

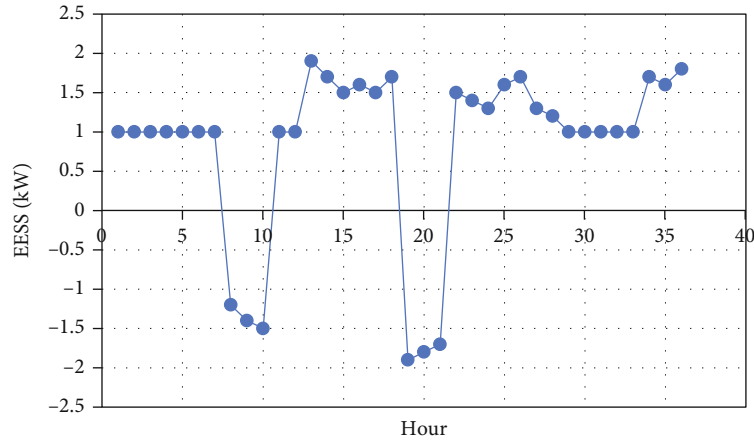


FIGURE 8: Power of EESS.

TABLE 6: Case 3 simulation.

State	Original peak demand	New peak demand (with EESS)	Reduction of regular energy cost
Case 3	3247.8 (kW)	4928.7 (kW)	193.2 (\$)

affects the cost of demand in case 1, increasing the SOC to the maximum is not achievable. The simulation results indicate that the EESS charged between 12:00 p.m. and 1:00 a.m. to equalize the ending SOC with a process of being developed. The EESS is collected from 12:00 p.m. to 1:00 p.m. because a model is only done with one day, and the cheapest cost is presented in the evening. Table 5 contains the findings from case 2.

5.2.3. Case 3. Since case 3 is a weekend demand, the peak is not as high. Simulating case 3 has the goal of confirming the EESS's power planning whenever the peak usage does not exceed the peak load that affects the cost of the demand. The EESS power output and SOC characteristics in Figure 8 are similar to those in case 2. The electricity cost is minimized without breaching the limitations because the original peak demand is modest. When using the EESS, the maximum force is increased by 539.6 kW in comparison to the initial peak demand; nevertheless, the demand cost is unaffected. Table 6 summarizes the findings of case 3.

6. Conclusion

From the work, the following conclusions are made:

- (i) Sensitivity analysis revealed only a minor rivalry between EESS and flexible bioenergy in the near and medium run. However, in areas where solar power is abundant, EESS can partially replace adaptable biofuels. Increased storage capabilities would have a diminishing marginal value since only

a restricted volume of information electrical power can be integrated into an electricity system because the EESS fleet's capability was a singularity problem giving to the negative residual demand peak

- (ii) As a result, flexible bioenergy supports EESS in the cases, and it provides a long-term storage alternative to EESS, which would otherwise be a primary participant. The EESS optimization method was created to arrange the outputs of the ESS in a structured manner in another energy management plan
- (iii) This method is divided into two stages: stage 1 was designed to reduce peak load associated with demanding costs, and stage 2 was intended to reduce total energy costs. There are three simulations used to ensure that the schedule was done correctly
- (iv) In a single building, the presented algorithms showed power management measures. This paper's contribution is that multiple kinds of technology can be regulated for the similar goal of peak demand decrease and costs of energy reducing

Data Availability

The data used to support the findings of this study are included within the article. Further data or information is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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