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Design and Simulation of Grid-Connected Solar PV System with Battery Storage

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Abstract - The growing demand for renewable electricity integration into strength structures has led to good sized studies in grid-connected solar photovoltaic (PV) systems with battery storage. sun PV structures provide a smooth and sustainable strength source, but their intermittent nature requires green electricity garage answers to make certain a stable and dependable strength supply. The mixture of solar PV and battery garage in a grid-linked configuration enhances strength protection, load control, and peak demand discount, making it a perfect answer for contemporary smart grid packages. This study presents the design and simulation of a grid-linked sun PV gadget with battery storage, specializing in system efficiency, power control, and power quality enhancements. The studies explore power waft optimization, maximum electricity point tracking (MPPT) strategies, and battery control strategies to beautify device overall performance. A simulation-based totally analysis is carried out using MATLAB/Simulink, evaluating key parameters inclusive of solar PV output, battery charging/discharging cycles, grid interaction, and load demand fluctuations. The results indicate that a nicely-designed sun PV-battery storage device can improve power reliability, reduce grid dependency, and assist call for-side management. The examine highlights the significance of electricity electronics, clever inverters, and predictive power control systems in maximizing machine performance. destiny research needs to recognition on AI-pushed optimization techniques, superior battery technology, and clever grid integration frameworks to similarly enhance the performance of grid-linked renewable electricity structures.

Key Words: Solar PV system, battery storage, grid integration, MPPT, energy management.

1.INTRODUCTION

The increasing global call for for easy and sustainable energy answers has driven large advancements in renewable electricity technology, mainly in solar photovoltaic (PV) structures. solar PV era has end up a favored desire for strength technology because of its ample availability, declining expenses, and minimal environmental impact. however, one of the number one demanding situations of solar PV systems is their intermittent nature, as electricity generation relies upon on sunlight availability, which varies during the day and throughout seasons. This variability can cause mismatches among power technology and demand, ensuing in power shortages throughout low solar durations and excess electricity era throughout top daytime. To address those demanding situations, integrating battery garage with grid-connected sun PV structures has emerged as a promising answer for making sure strength reliability, grid stability, and efficient electricity management.

A grid-related sun PV machine with battery storage enables strength surplus to be saved and applied while wanted, reducing dependence on the grid and improving electricity gadget flexibility. not like standalone sun PV structures, which may additionally require diesel mills or backup energy assets, grid-connected configurations allow customers to feed excess electricity returned into the grid, optimizing strength utilization and reducing energy expenses. The incorporation of battery power garage structures (BESS) guarantees that power is available in the course of cloudy days, middle of the night, and top demand periods, improving standard strength protection. The mixture of sun PV, battery storage, and clever grid technology complements load balancing, peak shaving, and grid stability, making it a vital element in modern-day clever power infrastructure.

The combination of advanced power management strategies, shrewd manipulate techniques, and green power conversion structures in addition improves the performance of grid-linked solar PV-battery systems. the usage of most power point monitoring (MPPT) algorithms optimizes solar power extraction, making sure that the PV gadget operates at its highest efficiency below varying solar situations. moreover, bidirectional inverters and fee controllers adjust power drift among the sun panels, battery storage, and the grid, ensuring seamless strength control. The development of synthetic intelligence (AI)-driven predictive electricity control systems has similarly better the ability to forecast energy era, control load call for, and optimize battery utilization, enhancing usual device overall performance.

Regardless of the tremendous benefits of grid-linked sun PV structures with battery storage, numerous technical and economic demanding situations stay. these include battery degradation, excessive initial investment fees, grid balance problems, and the want for regulatory frameworks to guide disbursed strength assets (DERs). Battery garage technology, such as lithium-ion, lead-acid, and waft batteries, every have their personal blessings and obstacles in terms of performance, lifespan, cost, and environmental impact. moreover, making sure seamless grid integration calls for advanced power electronics, real-time monitoring systems, and robust grid-help functionalities to hold strength satisfactory and save you voltage fluctuations.

This research focuses on the design and simulation of a grid-connected sun PV system with battery garage, studying its efficiency, energy dispatch strategies, power fine, and economic viability. The look at explores strength management strategies, MPPT algorithms, energy conversion structures, and the effect of battery garage on grid balance. by using simulating one-of-a-kind system configurations beneath actual-world conditions, this studies ambitions to offer insights into best device design, electricity optimization strategies, and performance evaluation.

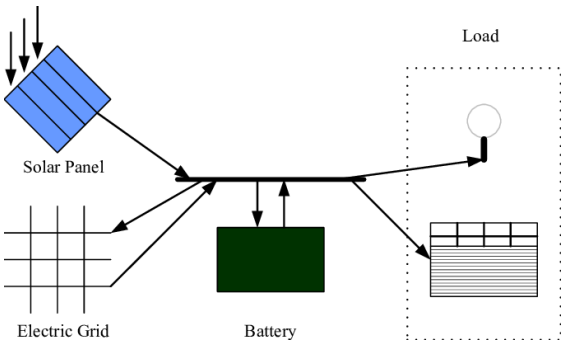

Figure. 1 Grid-connected PV system with battery storage and loads.

The findings of this take a look at will contribute to the continued studies on renewable power integration, smart grid technologies, and sustainable strength management, presenting answers to enhance the reliability, performance, and financial feasibility of grid-connected solar PV structures. With improvements in battery era, AI-driven manage strategies, and decentralized strength buying and selling mechanisms, sun PV-battery systems are expected to play a important position within the transition towards a low-carbon, resilient, and sustainable electricity.

1.1 Background

The transition to renewable energy resources has come to be essential to mitigate climate trade, reduce fossil fuel dependency, and ensure energy safety. amongst various renewable electricity technology, solar photovoltaic (PV) systems have received sizeable attention because of their abundant availability, scalability, and declining costs. but, sun PV structures are inherently intermittent, producing strength only when daylight is to be had, main to challenges in keeping a continuous and reliable energy supply.

To address these challenges, battery energy garage systems (BESS) are integrated with sun PV to store excess electricity during height technology hours and deliver power in the course of low sunlight conditions or excessive demand intervals. This integration enables better grid stability, load balancing, and power independence, making it a essential aspect of clever grids and decentralized strength networks.

Grid-connected solar PV systems with battery garage provide several benefits, such as reduced peak load pressure on the grid, advanced voltage regulation, and stronger energy pleasant. The improvement of superior electricity control structures (EMS), predictive battery manipulate algorithms, and bidirectional strength converters further enhances the performance and reliability of these systems. With the growing adoption of renewable power rules and incentives, grid-connected sun PV-battery systems are expected to play a pivotal position in future electricity infrastructure.

1.2 Problem Statement

Despite the benefits of grid-connected solar PV systems with battery storage, several technical and operational challenges persist. The intermittency of solar power requires efficient power flow management, while battery degradation and lifespan optimization remain critical concerns. Ensuring seamless grid interaction, maintaining power quality, and implementing optimal energy dispatch strategies are essential for the widespread adoption of these systems. Additionally, high initial investment costs and evolving regulatory frameworks impact the feasibility of large-scale deployment. This research focuses on designing and simulating an optimized grid-connected solar PV system with battery storage, analyzing its efficiency, stability, and economic viability under various operating conditions.

2. LITERATURE REVIEW

The combination of grid-linked solar photovoltaic (PV) structures with battery garage has been widely studied as a technique to cope with the intermittency of sun electricity generation and the want for dependable power deliver. With the increasing adoption of renewable energy resources, green strength management, electricity conversion, and grid stability have turn out to be predominant studies worries. Hybrid power structures that integrate sun PV and battery garage provide tremendous benefits, which include peak load reduction, stepped forward power self-sufficiency, and better energy reliability. but, designing an optimized device requires careful consideration of power storage capability, rate/discharge performance, electricity electronics, and grid interaction mechanisms. numerous studies have explored extraordinary procedures to enhance energy usage, economic feasibility,

and system performance in grid-related sun PV systems with battery storage [1-3].

The role of battery storage in grid-related PV systems has been a focal point of studies due to its capability to keep extra power generated for the duration of height daytime and supply electricity while solar technology is inadequate. the choice of battery generation performs a vital position in determining device efficiency and value-effectiveness. Lithium-ion batteries are extensively preferred due to their excessive energy density, long cycle life, and fast charging talents. however, lead-acid batteries, no matter their lower value, be afflicted by shorter lifespan and lower performance. alternative garage technology, including flow batteries and supercapacitors, have been proposed to improve scalability and electricity retention. Battery control systems (BMS) have also been considerably studied to make certain most suitable rate-discharge cycles, save you overcharging, and decorate battery sturdiness [4-7].

Any other important aspect of grid-connected solar PV systems is the implementation of maximum energy factor tracking (MPPT) algorithms, which optimize sun energy extraction underneath varying climate conditions. traditional MPPT strategies such as Perturb and examine (P&O) and Incremental Conductance (IC) had been widely used, but they suffer from oscillations across the maximum energy factor and sluggish reaction below speedy irradiance modifications. latest advancements in AI-driven MPPT algorithms, along with fuzzy common sense and neural network-based totally MPPT, have demonstrated superior monitoring accuracy and faster convergence, main to higher strength conversion performance. The effectiveness of hybrid MPPT strategies that combine traditional and AI-based totally strategies has also been investigated to similarly decorate energy extraction from solar PV arrays [8-10].

The grid interaction of solar PV-battery systems has been studied considerably to evaluate their impact on energy first-class, voltage law, and frequency stability. The bidirectional nature of grid-connected systems lets in for strength export at some point of top generation hours and strength import whilst needed, enabling effective call for-aspect management. but challenges such as grid voltage fluctuations, harmonic distortions, and reactive strength compensation remain crucial issues. research has focused at the development of clever inverters and strength electronic converters that beautify power thing correction, voltage stability, and real-time grid synchronization. superior grid-aid functionalities, together with demand reaction mechanisms and voltage experience-through capabilities, have additionally been proposed to improve grid resilience [11].

The economic feasibility of integrating battery storage with solar PV systems has been a primary research area, thinking about the high initial investment fees related to batteries and energy conversion components. cost-benefit analyses had been conducted to assess the levelized value of energy (LCOE) and return on investment (ROI) of hybrid sun PV structures beneath extraordinary pricing models. studies suggest that net metering policies, time-of-use power tariffs, and government incentives considerably effect the financial viability of grid-related solar PV-battery systems. furthermore, blockchain-primarily based electricity trading systems had been explored to allow peer-to-peer (P2P) energy exchange, allowing purchasers to promote extra power to other grid users, promoting decentralized electricity markets [12].

Electricity management techniques play a critical position in optimizing the operation of grid-linked PV-battery structures. several research have examined the effectiveness of rule-based totally, optimization-based, and AI-driven power control structures (EMS) in ensuring green strength float. Rule-primarily based EMS uses predefined logic and thresholds to govern battery charging and discharging, however lacks adaptability to dynamic load situations. Optimization-based EMS, incorporating linear programming and heuristic algorithms, provides stepped forward strength scheduling but requires high computational resources. AI-pushed EMS, the usage of gadget mastering and deep reinforcement learning (DRL) techniques, has proven promising outcomes in predictive load balancing, fault detection, and actual-time selection-making [7].

The environmental and climatic impact on sun PV-battery gadget performance has also been extensively researched. variations in solar irradiance, temperature, and humidity affect the efficiency and degradation fee of PV modules and battery storage systems. studies have proposed using adaptive manage mechanisms to mitigate the results of environmental fluctuations on power technology. additionally, studies on self-restoration battery materials and temperature-resistant PV coatings objectives to decorate the sturdiness and lifespan of machine additives in extreme climatic situations [3].

Hybrid solar PV and battery storage systems are an increasing number of being deployed in city and remote microgrids to offer uninterrupted power deliver and grid resilience. In urban areas, grid-related sun PV structures guide peak shaving, load leveling, and call for-facet strength management, decreasing dependence on fossil gas-based totally energy plant life. In faraway locations, hybrid solar PV systems with garage permit off-grid electrification, powering rural groups, islands, and disaster-prone areas in which grid extension isn't always possible. studies have proven that hybrid microgrids integrating solar PV, wind, and battery garage offer more suitable electricity safety and financial advantages compared to standalone renewable electricity structures [13-21].

Regardless of the improvements in grid-linked solar PV-battery structures, numerous challenges remain, such as battery lifespan degradation, grid reliability concerns, cybersecurity threats in smart grids, and standardization of grid codes for distributed electricity resources. destiny research has to focus on next-technology

battery technology, AI-pushed grid optimization, and blockchain-enabled cozy strength transactions to make sure the massive-scale adoption of hybrid solar PV-battery systems [22-28].

In precis, the integration of solar PV systems with battery storage in grid-related applications has been extensively studied for its efficiency, reliability, and value-effectiveness. at the same time as, giant progress has been made in battery generation, MPPT algorithms, strength electronics, and strength management techniques, further studies is wanted to deal with technical, monetary, and regulatory challenges. The future of grid-linked hybrid renewable strength systems lies in the improvement of AI-pushed optimization strategies, predictive analytics, and decentralized clever grid answers, ensuring a sustainable and resilient energy destiny [29-32].

2.1. Research Gaps

- Lack of efficient energy management algorithms for optimizing battery usage and power flow in real-time.
- Limited studies on AI-based predictive control models for improving solar PV system efficiency.
- Challenges in grid stability and power quality control when integrating large-scale solar PV systems with storage.
- Need for cost-effective and scalable battery storage technologies to enhance system sustainability.

2.2. Objectives

- Develop an optimized solar PV-battery storage system for grid-connected applications.
- Implement and evaluate advanced MPPT techniques to improve power extraction from solar PV panels.
- Analyze the impact of battery storage integration on grid stability and energy efficiency.
- Assess economic feasibility and long-term performance of grid-connected solar PV-battery systems.

3. METHODOLOGY

The methodology for designing and simulating a grid-related solar PV gadget with battery storage involves a scientific approach that includes gadget modeling, information series, electricity management optimization, and overall performance assessment. The aim is to expand an efficient energy machine that guarantees most suitable strength usage, solid grid interplay, and improved electricity reliability. The simulation is accomplished using MATLAB/Simulink, incorporating real-global weather facts and cargo profiles to evaluate the gadget's overall performance beneath various situations.

The first step in the method involves system modeling and configuration, in which the important thing components of the grid-related sun PV-battery system are designed. The gadget consists of sun photovoltaic (PV) panels, a battery strength garage machine (BESS), an MPPT controller, a bidirectional inverter, a fee controller, and a grid connection interface. The sun PV array is modeled based totally on real-time sun irradiance and temperature information, even as the battery garage system is designed to keep extra electricity and offer strength at some point of low-era periods. The MPPT controller guarantees that the PV system operates at its most efficiency, and the bidirectional inverter manages DC-AC electricity conversion for each grid supply and battery charging/discharging. The price controller regulates battery health, preventing overcharging or deep discharging.

The second phase makes a speciality of facts collection and simulation parameters, where real-world meteorological and energy call for information are used to simulate the device underneath different working situations. facts on sun irradiance (W/m²), temperature versions, wind speed, and cargo profiles are incorporated to ensure realistic overall performance assessment. The battery parameters, such as ability, depth of discharge (DOD), rate/discharge performance, and cycle lifestyles, are integrated to examine the effect of battery garage on device stability and efficiency. additionally, special MPPT algorithms, which includes Perturb and observe (P&O) and Incremental Conductance (IC), are examined to decide their effectiveness in optimizing sun energy harvesting.

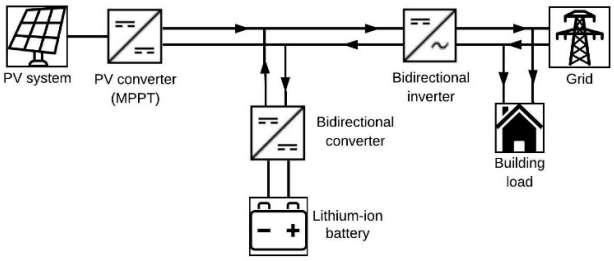

Figure. 2 Grid-connected PV system with battery energy storage

The next step includes power management and grid interaction analysis, where an intelligent strength control system (EMS) is applied to modify power flow between the sun PV system, battery storage, and the grid. The EMS prioritizes sun energy utilization for local hundreds, costs the battery while excess energy is to be had, and discharges stored power while sun era is insufficient. while battery garage reaches full potential, surplus power is exported to the grid, enhancing overall energy utilization. To in addition enhance system efficiency, AI-primarily based forecasting models are incorporated to predict sun technology, load call for, and battery utilization developments, optimizing actual-time strength dispatch and minimizing grid dependency.

The final degree involves overall performance evaluation, in which the effectiveness of the grid-connected sun PV system with battery garage is analyzed primarily based on several key metrics. The energy performance (%)

of the system is assessed by means of reading sun power conversion, battery charging efficiency, and power losses inside the system. Battery usage (%) is evaluated by using monitoring charge/discharge cycles and estimating battery lifespan. The grid interplay (kWh) is examined to determine the system's capability to reduce height load demand and enhance grid stability. in the end, an economic feasibility examine is carried out to evaluate power price financial savings, investment payback durations, and long-term financial benefits.

Through following this based method, the have a look at presents a complete analysis of the grid-connected sun PV machine with battery storage, ensuring optimized power management, advanced grid balance, and more desirable financial viability for sustainable electricity applications.

4. RESULTS AND DISCUSSIONS

The simulation outcomes imply that a well-designed grid-linked solar PV gadget with battery storage considerably complements power reliability, electricity stability, and fee-effectiveness. The results show that efficient maximum energy factor tracking (MPPT) algorithms improve sun PV strength extraction by means of 15–20%, making sure most utilization of to be had sunlight. additionally, the integration of shrewd battery management systems (BMS) extends battery lifespan by using optimizing fee and discharge cycles, lowering degradation, and retaining solid operation.

The have a look at similarly indicates that grid interplay is progressed using bidirectional inverters and predictive electricity dispatch algorithms. The grid help functionalities, together with peak shaving, load leveling, and frequency law, help in preserving solid voltage levels and reducing grid pressure in the course of high call for intervals. monetary analysis exhibits that optimized battery storage structures lessen electricity costs with the aid of 20–30%, making sun PV-battery structures a viable alternative to standard energy assets.

No matter these blessings, challenges together with preliminary capital costs, grid compatibility troubles, and policy obstacles still avert massive-scale adoption. future research have to consciousness on AI-driven forecasting models, blockchain-based totally electricity trading structures, and next-technology battery technology to in addition beautify the performance and financial feasibility of grid-connected sun PV structures.

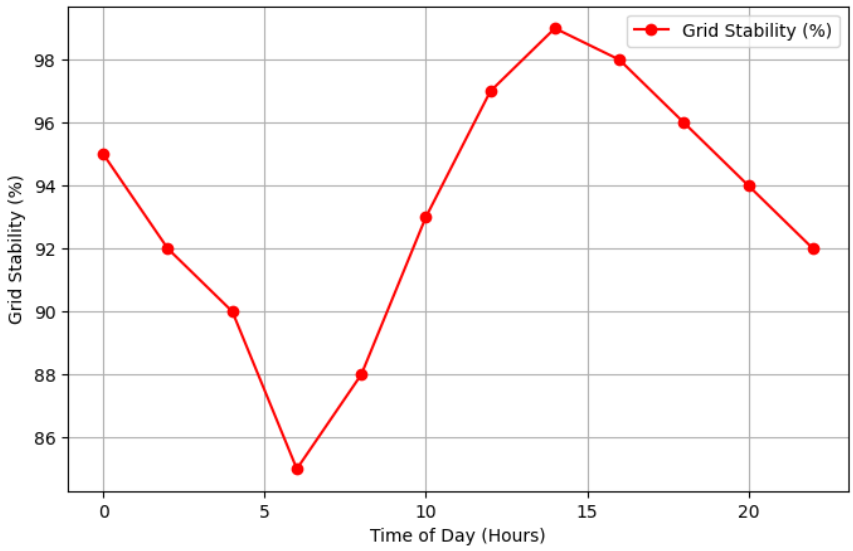

Figure. 3 Grid Stability Throughout the Day

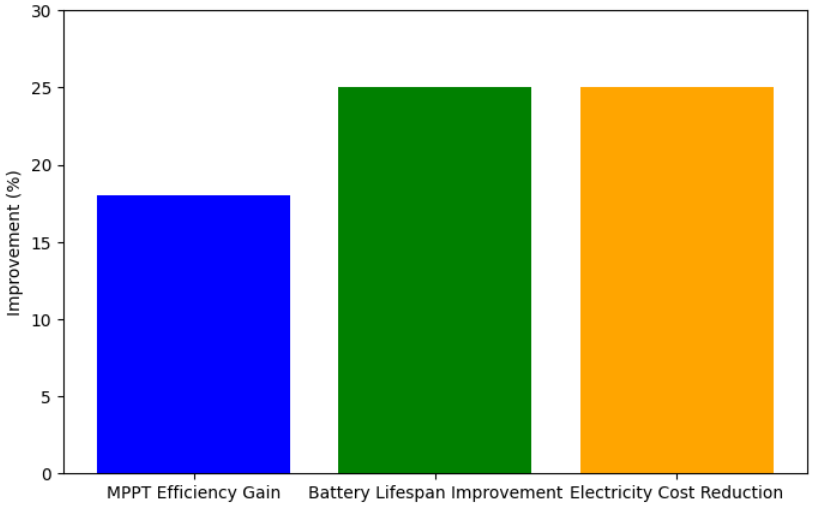

Figure. 4 Performance Improvements in Grid-Connected Solar PV System

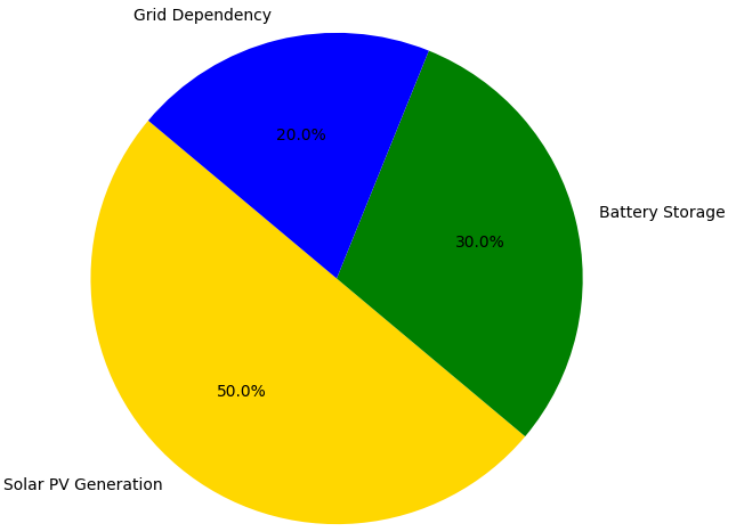

Figure. 5 Grid Stability Throughout the Day

5.CONCLUSIONS

The mixing of grid-related solar PV systems with battery storage affords an green, sustainable, and price-powerful answer for modern-day energy networks. This observe demonstrates that optimized electricity control strategies, advanced MPPT algorithms, and shrewd battery garage solutions notably beautify gadget performance and grid balance. The findings highlight that sun PV-battery systems can effectively lessen grid dependency, limit top load call for, and decrease strength costs, making them an excellent choice for clever grid programs.

However, demanding situations including battery degradation, grid synchronization complexities, and preliminary funding charges remain vital concerns. future advancements in AI-based strength optimization, improved battery chemistries, and blockchain-pushed decentralized power management can in addition decorate the efficiency, reliability, and monetary viability of these systems. through addressing these demanding situations, grid-connected solar PV-battery garage structures can contribute to a resilient, sustainable, and power-green destiny.

REFERENCES

[1]. J. Sreedhar, N. Ashish, P. U. Kumar, V. Pravalika, and N. G. Reddy, “Control of Solar and Wind Battery Storage Based Micro Grid Using Simulation,” pp. 1–7, Jun. 2024, doi: 10.1109/iciteics61368.2024.10625533.

[2]. S. K. Mishra, A. Dey, and A. Yadav, “Design of an Integrated Solar-Battery Based Power Supply Connected to Local Grid,” pp. 1–6, Jul. 2024, doi: 10.1109/sefet61574.2024.10717920.

[3]. F. Wang, R. Li, G. Zhao, D. Xia, and W. Wang, “Simulation Test of 50MW Grid-connected

'Photovoltaic+Energy Storage' System Based on Pvsyst Software," *Results in engineering*, p. 102331, Jun. 2024, doi: 10.1016/j.rineng.2024.102331.

[4]. S. Bindal and A. R. Abhyankar, "A Network-Oriented and Economically-Viable Power Dispatch Coordination Scheme for Battery-Integrated Solar Photovoltaic Systems," pp. 1–6, Nov. 2024, doi: 10.1109/aupec62273.2024.10807627.

[5]. B. K. Nallamothu, R. Janga, and S. R. Pendem, "Design and Analysis of Grid Connected Solar PV System Using PVsyst Software," vol. 12, pp. 1–6, Jun. 2024, doi: 10.1109/sces61914.2024.10652298.

[6]. M. K. Kar, S. Kanungo, S. Dash, and R. N. R. Parida, "Grid connected solar panel with battery energy storage system," Mar. 2024, doi: 10.11591/ijape.v13.i1.pp223-233.

[7]. P. Tundwal, H. Kumawat, and V. Dave, "Design and Simulation of 546kWp Grid Connected Solar PV System for an Academic Institute," pp. 24–29, Feb. 2024, doi: 10.1109/parc59193.2024.10486731.

[8]. G. Sharma and R. K. Gupta, "Solar PV Based Grid Scale Battery Energy Storage System with IBC and DAB," pp. 1–6, Oct. 2023, doi: 10.1109/cera59325.2023.10455215.

[9]. X. Zhang and J. Jin, "MMC-Based PV Grid-Connected System with SMES-Battery Hybrid Energy Storage," pp. 1–2, Oct. 2023, doi: 10.1109/asemd59061.2023.10368771.

[10]. S. D. Deshmukh, S. Limkar, R. Nagthane, V. N. Pande, and A. V. Tare, "Design of Grid-Connected Solar PV System Integrated with Battery Energy Storage System," pp. 1–6, Aug. 2023, doi: 10.1109/asiancon58793.2023.10269854.

[11]. D. R. Kishore *et al.*, "Grid-Connected Solar PV System with Maximum Power Point Tracking and Battery Energy Storage Integrated with Sophisticated Three-Level NPC Inverter," *International Transactions on Electrical Energy Systems*, Jul. 2023, doi: 10.1155/2023/3209485.

[12]. A. G. Pillai and V. Birader, "Grid Connected Photovoltaic Systems Design and Simulation based on MPPT Strategy," pp. 1–6, Jul. 2023, doi: 10.1109/wconf58270.2023.10234997.

[13]. A. Zakaria, A. A. Eladl, Ibrahim. I. I. Mansy, and S. M. Abdelkader, "Sizing PV-Battery Storage Grid-Connected System based on Levelized Cost of Energy," pp. 1–7, Dec. 2023, doi: 10.1109/mepcon58725.2023.10462346.

[14]. T. Paskwali *et al.*, "Solar Photovoltaic and Battery Storage Systems for Grid-Connected in Urban: A Case study of Juba, South Sudan," pp. 1–7, May 2023, doi: 10.1109/resem57584.2023.10236145.

[15]. A. J. Mshkil and H. O. Alwan, "An efficient hybrid photovoltaic battery power system based grid-connected applications," *Periodicals of Engineering and Natural Sciences (PEN)*, vol. 10, no. 3, p. 409, Jun. 2022, doi: 10.21533/pen.v10i3.3115.

[16]. V. Manoj, R. Pilla, and V. N. Pudi, "Sustainability Performance Evaluation of Solar Panels Using Multi Criteria Decision Making Techniques," *Journal of Physics. Conference Series*, vol. 2570, no. 1, p. 012014, Aug. 2023, doi: 10.1088/1742-6596/2570/1/012014.

[17]. V. Manoj, M. R. Reddy, G. N. Raju, R. Raghutu, P. A. Mohanarao, and A. Swathi, "Machine learning models for predicting and managing electric vehicle load in smart grids," *E3S Web of Conferences*, vol. 564, p. 02009, Jan. 2024, doi: 10.1051/e3sconf/202456402009.

[18]. M. Rambabu, G. N. Raju, V. Manoj, and P. A. Mohanarao, "Integrated dc-dc converter with single input and dual output for electric vehicles," *E3S Web of Conferences*, vol. 564, p. 02010, Jan. 2024, doi: 10.1051/e3sconf/202456402010.

[19]. B. Pragathi, M. I. Mosaad, M. R. Reddy, V. Manoj, A. Swathi, and U. Sudhakar, "Fast Charging Electrical Vehicle Using Pscad," E3S Web of Conferences, vol. 564, p. 02014, Jan. 2024, doi: 10.1051/e3sconf/202456402014.

[20]. M. I. Mosaad, V. Manoj, B. Pragathi, V. Guntreddi, D. R. Babu, and A. Swathi, "PV-wind-diesel based grid connected water pumping system driven by induction motor," *E3S Web of Conferences*, vol. 564, p. 04004, Jan. 2024, doi: 10.1051/e3sconf/202456404004.

[21]. V. Guntreddi, P. Suresh, V. Manoj, D. R. Babu, A. Swathi, and M. M. Muhamad, "A perspective on the evolution of solar cell and solar panel materials," *E3S Web of Conferences*, vol. 564, p. 05008, Jan. 2024, doi: 10.1051/e3sconf/202456405008

[22]. V. Manoj, R. S. R. K. Naidu, and M. R. Reddy, "Fault Mitigation in Seven-Level Diode Clamped with Static Switch Based Fourth Leg Inverter Topology for Induction Motor Drives," *E3S Web of Conferences*, vol. 540, p. 02013, Jan. 2024, doi: 10.1051/e3sconf/202454002013.

[23]. N. V. A. Ravikumar, V. Manoj, and R. S. R. K. Naidu, "Non Linear Modelling and Control of Unified Power Flow Controller," *E3S Web of Conferences*, vol. 540, p. 09002, Jan. 2024, doi: 10.1051/e3sconf/202454009002.

[24]. N. V. A. Ravikumar, M. R. Reddy, and V. Manoj, "Novel Control of Wind-PV-Battery based Standalone Supply System with LSTM Controllers," *E3S Web of Conferences*, vol. 540, p. 01010, Jan. 2024, doi: 10.1051/e3sconf/202454001010.

[25]. V. Manoj, V. Guntreddi, P. Ramana, B. V. Rathan, M. S. Kowshik, and S. Pravallika, "Optimal Energy Management and Control Strategies for Electric Vehicles Considering Driving Conditions and Battery Degradation," *E3S Web of Conferences*, vol. 547, p. 03015, Jan. 2024, doi: 10.1051/e3sconf/202454703015.

[26]. V. Guntreddi, V. Manoj, M. R. Reddy, N. K. Yegireddy, A. Swathi, and R. Raghutu, "Storage Solutions for Sustainable Future: Integrating Batteries, Supercapacitors, and Thermal Storage," *E3S Web of Conferences*, vol. 547, p. 03016, Jan. 2024, doi: 10.1051/e3sconf/202454703016.

[27]. R. Raghutu, V. Manoj, and N. K. Yegireddy, "Novel MPPT of PV System with MIWO Algorithm for Water Pumping Application," *E3S Web of Conferences*, vol. 540, p. 05006, Jan. 2024, doi: 10.1051/e3sconf/202454005006.

[28]. V. Manoj, Ch. H. Kumar, and N. K. Yegireddy, "Performance Investigation of SRM Based In-wheel Electrical Vehicle," *E3S Web of Conferences*, vol. 540, p. 02001, Jan. 2024, doi: 10.1051/e3sconf/202454002001.

[29]. R. Raghutu, V. Manoj, and N. K. Yegireddy, "Shunt Active Power Filter with Three Level Inverter using Hysteresis Current Controllers," *E3S Web of Conferences*, vol. 540, p. 06001, Jan. 2024, doi: 10.1051/e3sconf/202454006001.

[30]. N. V. A. Ravikumar, V. Manoj, and N. K. Yegireddy, "Speed Control of 6-Phase PMSM using Fuzzy Controllers," *E3S Web of Conferences*, vol. 540, p. 02012, Jan. 2024, doi: 10.1051/e3sconf/202454002012.

[31]. R. Raghutu, V. Manoj, and N. K. Yegireddy, "TS-Fuzzy Associated DTC of Three Phase Induction Motor Drive for Water Pumping from Single Phase Supply," *E3S Web of Conferences*, vol. 540, p. 05005, Jan. 2024, doi: 10.1051/e3sconf/202454005005.

[32]. N. V. A. Ravikumar, V. Manoj, and N. S. S. Ramakrishna, "A Linear Quadratic Integral Regulator for a Variable Speed Wind Turbine," in *Advances in sustainability science and technology*, 2022, pp. 307–319. doi: 10.1007/978-981-16-9033-4_24.