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Hybride Inverter for Solar Based Applications

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ABSTRACT: In general, Sun Photovoltaic (SPV) is incorporated to lattice through a DC converter and Voltage Source Converter (VSC) for genuine power infusion (called two-stage transformation). Considering productivity point, the single-stage transformation becomes well known and in which Greatest Power Point Following (MPPT) of SPV and genuine power infusion are accomplished with VSC alone. In any case, if Battery Energy Stockpiling (BES) upheld by bidirectional DC converter is introduced in the single-stage change framework, then co-appointment between DC converter and VSC is expected to accomplish synchronous activity of MPPT and genuine power infusion. In this paper, an organized control of single stage matrix associated SPV and BES framework is proposed alongside energy the board.

A planned control of single stage matrix associated SPV and BES framework is proposed alongside energy the board. In which, the calculation organizes VSC and bidirectional DC converter in light of the Territory of Charge (soc) of the battery to such an extent that MPPT and power infusion is accomplished at the same time. The proposed strategy infusing genuine power, yet in addition attempts to remunerate load receptive power and lopsided impartial current minimization. Further, a functioning amendment activity during non-SPV hours is examined for better use of VSC limit. Here we associated the bidirectional dc - dc converter for charging and releasing of voltage.

I. INTRODUCTION

SOLAR PHOTOVOLTAIC (SPV) ENERGY Solar Photovoltaic (SPV) energy systems and their integration into grid-connected systems highlights key aspects of their operation and importance in renewable energy generation. Here's a more detailed breakdown of the concepts mentioned

RENEWABLE ENERGY SOURCE:

SPV energy harnesses sunlight and converts it into electricity using photovoltaic cells. This process is clean and sustainable, contributing to the reduction of greenhouse gas emissions

Spvs can be installed in various locations, from residential rooftops to large solar farms, facilitating distributed generation. This decentralization enhances energy security and reduces transmission losses

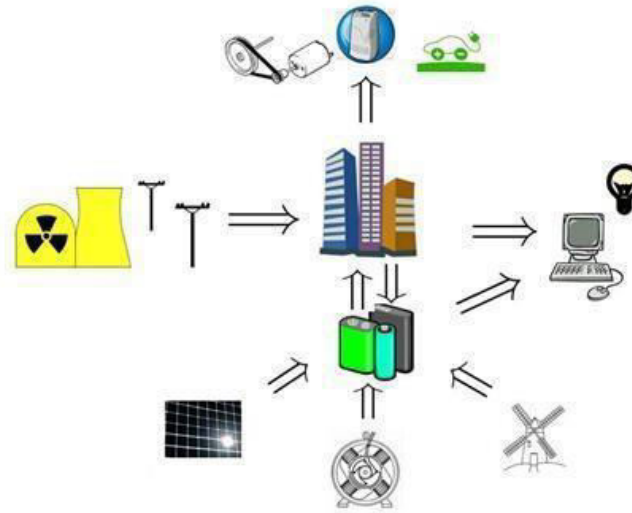
GRID-CONNECTED SPV SYSTEMS

In grid-connected SPV systems, hybrid inverters allow for seamless integration with the utility grid, enabling energy flow both ways.

During peak solar generation, excess power generated by the solar panels can be used to charge the battery storage or fed back to the grid, reducing dependency on grid power and potentially earning credits through net metering.

When solar production is low, such as during cloudy days or nighttime, the inverter intelligently draws power from either the battery or the grid, depending on what is most cost effective.

Battery Energy Storage System (BESS)



II. TECHNIQUES OF HYBRID INVERTER

GRID-TIED AND OFF-GRID FUNCTIONALITY

One of the core features of hybrid inverters is their ability to operate in both grid-tied and off-grid modes. In grid-tied mode, the inverter allows solar energy to be fed into the grid while simultaneously supplying power to the home or business. Any excess energy that is not consumed can be sent to the utility grid, often resulting in credits or payments through net metering.

In off-grid mode, the hybrid inverter uses stored energy from batteries to supply power to the load when there is no grid connection or during power outages. This dual-mode capability enhances energy security and enables greater flexibility in different geographical areas or applications where grid access is unreliable or unavailable.

ENERGY STORAGE INTEGRATION

Hybrid inverters are designed to seamlessly integrate with energy storage systems (ESS) like lithium-ion or lead-acid batteries. This integration allows excess solar energy generated during the day to be stored in the batteries for use at night or during cloudy periods. The inverter manages the charge and discharge cycles of the battery, ensuring that energy is stored efficiently and released when needed. Advanced algorithms optimize the flow of energy between the solar panels, batteries, and load, helping users maximize self-consumption and reduce dependency on the grid. This feature is particularly beneficial for households or businesses looking to reduce electricity bills, increase grid independence, and ensure uninterrupted power supply during blackouts.

MAXIMUM POWER POINT TRACKING (MPPT) OPTIMIZATION

Maximum Power Point Tracking (MPPT) is a critical technique used in hybrid inverters to maximize the efficiency of solar power generation. The MPPT technology ensures that the solar panels operate at their optimal power output by constantly adjusting the operating point to capture the maximum amount of solar energy available under varying environmental conditions. The inverter uses MPPT to monitor factors such as temperature, sunlight intensity, and panel angle to optimize energy harvesting. With multiple MPPT trackers, some hybrid inverters can manage different solar panel strings with varying shading conditions, allowing each string to operate at its ideal efficiency. This capability ensures that the solar system delivers the highest possible power output.

III. APPLICATIONS

1. RESIDENTIAL SOLAR POWER SYSTEMS

Hybrid inverters are widely used in residential solar power systems to integrate solar energy with energy storage. Homeowners can utilize the energy generated by their solar panels during the day and store excess power in batteries for use at night or during outages. This reduces electricity bills, provides backup power, and improves energy

independence. The hybrid inverter automatically switches between solar, battery, and grid power to optimize energy usage. With this technology, homeowners can increase self-consumption of solar energy, thereby reducing reliance on the grid.

2. COMMERCIAL SOLAR POWER SYSTEMS

Commercial establishments with large energy needs can benefit greatly from hybrid inverters. These systems allow businesses to harness solar energy during the day while storing excess electricity for use during peak demand times or when solar production is low. This energy storage helps avoid peak-hour grid rates, improving cost efficiency. Hybrid inverters also offer scalability, making it easier for businesses to expand their energy storage as their needs grow. By integrating energy storage with solar power, commercial buildings can enhance their energy resilience and contribute to sustainability.

3. OFF-GRID SOLAR SYSTEMS

Hybrid inverters are essential for off-grid solar systems, where there is no access to the utility grid. These systems rely on solar energy and stored battery power to supply electricity to homes, cabins, or remote areas. The hybrid inverter ensures a smooth transition between solar power and battery backup. It optimizes battery charging and discharging to maintain power supply when solar generation is insufficient. This application is crucial for providing reliable and independent electricity to locations without grid infrastructure.

4. MICROGRIDS AND COMMUNITY SOLAR PROJECTS

Hybrid inverters are key components in microgrids and community solar projects. These decentralized systems provide energy to small communities or specific groups of users. By combining solar generation and energy storage, hybrid inverters enable microgrids to operate independently of the main grid, ensuring energy security during grid outages. They allow for optimized energy distribution and management within the community, reducing reliance on external energy sources. Additionally, hybrid inverters help improve the economic viability of such projects by increasing self-consumption and reducing operational costs.

5. ELECTRIC VEHICLE (EV) CHARGING STATIONS

Hybrid inverters can also be integrated into electric vehicle (EV) charging stations to provide renewable energy for EV charging. These inverters can store solar energy during the day and supply it to EVs when needed, reducing the need for grid power. This integration helps promote the use of green energy in transportation and supports the growing demand for electric vehicles. Hybrid inverters can be programmed to prioritize solar energy use, optimizing the efficiency of charging stations and reducing the environmental impact of EV infrastructure.

6. AGRICULTURAL SOLAR APPLICATIONS

In agricultural settings, hybrid inverters are used to power irrigation systems, greenhouses, and other farm-related energy needs. By integrating solar power with energy storage, farmers can reduce their reliance on diesel generators and grid electricity, improving sustainability and cost-efficiency. Hybrid inverters allow for efficient energy management, ensuring that solar power is used when available and stored for use during non-sunny periods. This application is particularly valuable in remote areas where energy access may be limited, offering reliable and environmentally friendly energy solutions.

7. REMOTE TELECOM SITES

Remote telecom towers often rely on hybrid solar systems to provide a continuous power supply. These towers are located in areas without reliable access to the grid, making solar power an ideal solution. Hybrid inverters enable these sites to store excess solar energy for use at night or during cloudy days, ensuring uninterrupted communication services. The hybrid inverter manages both solar energy production and battery storage to maintain a constant power supply for critical telecom infrastructure, reducing operational costs and the need for fuel-powered backup generators.

8. PEAK SHAVING AND LOAD SHIFTING IN INDUSTRIAL APPLICATIONS

Industrial facilities use hybrid inverters for peak shaving and load shifting, where stored solar energy is used during periods of high demand to reduce reliance on the grid. By charging batteries with excess solar energy during off-peak hours, businesses can draw from stored power during peak times, when electricity costs are higher. This not only reduces energy costs but also improves the efficiency of the overall energy system. Hybrid inverters enable industries to maintain smooth operations while minimizing their carbon footprint and dependence on fossil fuels.

9. BACKUP POWER SYSTEMS FOR CRITICAL INFRASTRUCTURE

Hybrid inverters are an essential part of backup power systems for critical infrastructure, such as hospitals, data centers, and emergency response facilities. In these applications, hybrid inverters ensure that solar energy is harnessed and stored for use during grid outages. The system can provide seamless switching between solar power, stored energy, and grid power to maintain uninterrupted operations. This application is crucial for maintaining the integrity of essential services, providing resilience in the face of power failures. **CHARACTERISTICS OF A BATTERY ENERGY STORAGE SYSTEM**

ROUND-TRIP EFFICIENCY:

Shows how much usable energy that can be released from a capacity framework comparative with how much energy that was placed in. This records for the energy lost during each charge and release cycle. Common qualities range from 60% to 95%.

ENERGY DENSITY:

How much energy that can be put away for a given measure of region, volume, or mass. This standard is significant in applications where region is a restricting component, for instance, in a metropolitan substation where space could be a restricting imperative to site energy capacity.

POWER DENSITY:

Power thickness demonstrates how much power that can be conveyed for a given measure of region, volume, or mass. Moreover, similar to energy thickness, power thickness shifts altogether among capacity types. Once more, power thickness is significant if region and additionally space are restricted or on the other hand on the off chance that weight is an issue.

PROPOSED SYSTEM

The proposed framework with bidirectional dc - dc converter is sent for bidirectional dc - dc converter for charging and releasing of voltage, In a proposed matrix associated Sunlight based Photovoltaic (SPV) framework with a bidirectional DC converter, the framework is upgraded with extra highlights, for example, energy capacity and bidirectional power stream. This empowers more productive energy the board, further develops lattice security, and takes into consideration energy capacity to be coordinated successfully. Here is a breakdown of the proposed framework and how a bidirectional DC converter squeezes into it.

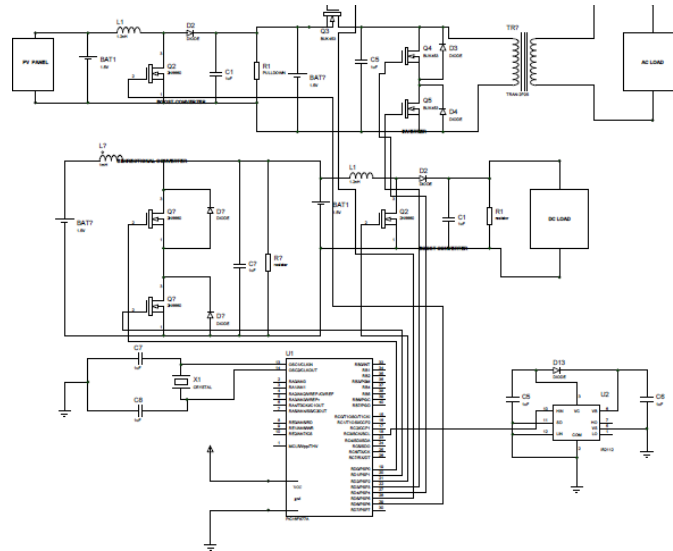
ADVANTAGES

- It perform high accuracy.
- It detected in real time.
- low risk, and cost effective.
- Scope of improvement.
- Efficient of handling things.

IMPLEMENTATION

The implementation of the proposed framework with a bidirectional DC-DC converter for a sunlight-based Photovoltaic (SPV) system involves integrating several components to optimize energy management, improve grid stability, and enhance energy storage. The primary function of the bidirectional DC-DC converter is to facilitate both the charging and discharging of the energy storage system, such as batteries, while ensuring efficient energy flow between the photovoltaic panels, the storage unit, and the power grid. In this configuration, the converter operates in two modes: during sunlight hours, it charges the batteries using excess energy generated by the PV panels, and during periods of low solar generation (e.g., nighttime or cloudy conditions), it discharges the stored energy to meet the demand.

SYSTEM ARCHITECTURE



MODULES

- Matlab
- System Modeling and Configuration
- Control Strategy Development.
- Simulation of Different Operating Modes
- Performance Evaluation and Optimization.

III. MODULES DESCRIPTION

1. MATLAB

To design and implement a hybrid inverter for a solar-based application using MATLAB, the proposed work module typically involves multiple stages, including system modeling, control design, simulation, and testing. MATLAB and its Simulink environment provide a comprehensive platform to model the energy flows, develop control strategies, and evaluate the performance of the hybrid inverter.:

2. SYSTEM MODELING AND CONFIGURATION

OBJECTIVE:

Create a complete model of the hybrid inverter system, incorporating components such as solar panels, batteries, DC-DC converters, inverters, and loads.

STEPS:

Battery Modeling: Represent the battery as a storage device with charging and discharging characteristics, including parameters like State of Charge (SOC) and Depth of Discharge (DOD). This model should accurately reflect the battery's behavior over time and different load conditions.

DC-DC Converter Design: Design a DC-DC boost converter to step up the voltage from the PV array to a suitable level for charging the battery or feeding into the inverter. MATLAB's Simulink allows for modeling of switching components and controls..

$$I = I_{sc} \frac{G}{G_{ref}} \left(1 - \exp \left(- \frac{V + IR_s}{V_T} \right) \right)$$

3. CONTROL STRATEGY DEVELOPMENT.

OBJECTIVE:

Create a complete model of the hybrid inverter system, incorporating components such as solar panels, batteries, DC-DC converters, inverters, and loads.

STEPS:

Solar PV Array Modeling: Model the solar photovoltaic (PV) array as a DC source with varying output based on irradiance and temperature. MATLAB's Simulink and Simscape Electrical libraries have blocks to accurately model the I-V and P-V characteristics of the PV modules.

Battery Modeling: Represent the battery as a storage device with charging and discharging characteristics, including parameters like State of Charge (SOC) and Depth of Discharge (DOD). This model should accurately reflect the battery's behavior over time and different load conditions.

4. SIMULATION OF DIFFERENT OPERATING MODES

OBJECTIVE

Simulate and evaluate the hybrid inverter's performance under various operating modes using MATLAB's Simulink environment.

MODES TO SIMULATE

Grid-Tied Mode: Simulate the operation where the hybrid inverter is connected to the grid, supplying power to the load and feeding excess energy to the grid.

Off-Grid Mode: Test the system's ability to operate in an islanded condition, supplying power to local loads using solar and battery sources only.

5. PERFORMANCE EVALUATION AND OPTIMIZATION

OBJECTIVE:

Evaluate the performance of the hybrid inverter system to ensure it meets efficiency and power quality requirements.

STEPS:

Efficiency Analysis: Measure the overall system efficiency by tracking power losses in each component (PV, battery, inverter, and grid interaction). MATLAB's data logging and analysis tools can help visualize efficiency under different load and irradiance conditions.

Energy Storage Optimization: Analyze the battery usage patterns to ensure optimal charging and discharging cycles, enhancing battery life and reducing costs.

IV. CONCLUSION

In conclusion, a hybrid inverter in a grid-connected system provides a versatile and efficient solution for integrating renewable energy sources like solar photovoltaics (SPV) with energy storage. Hybrid inverters can manage both direct solar energy generation and battery storage, allowing for flexible power distribution to meet real-time energy needs. During peak solar generation, the inverter prioritizes power supply to local loads, charges the battery, and exports any surplus to the grid, ensuring maximum utilization of solar energy.

The integration of a hybrid inverter enhances grid stability by providing support during peak demand periods and supplying power to critical loads during outages. The inverter's capability to seamlessly switch between grid-tied and off-grid modes ensures a reliable power supply and energy independence, contributing to grid resilience and reducing dependency on non-renewable energy sources.

This hybrid inverter-based system offers a sustainable, user-friendly, and scalable approach to energy management. It supports the global shift towards renewable energy and provides a pathway for individuals, communities, and industries to achieve energy efficiency, cost savings, and carbon footprint reduction. As advancements in inverter technology continue, hybrid inverters are likely to play a pivotal role in the widespread adoption of renewable energy, enabling a sustainable and reliable energy future.

V. FUTURE ENHANCEMENT

One of the most promising advancements is the integration of hybrid inverters with smart grid technologies and the Internet of Things (IoT). By connecting hybrid inverters to smart meters, sensors, and cloud-based platforms, these systems can provide real-time data and analytics on energy generation, consumption, and storage.

This connectivity allows for dynamic energy management, where the inverter can automatically adjust its operation based on demand response signals from the grid, user preferences, or predictive analytics. Smart grid integration will allow hybrid inverters to interact more efficiently with the grid, optimizing energy flow, reducing transmission losses, and enhancing grid stability.

The future of hybrid inverters holds tremendous promise in revolutionizing the way renewable energy is integrated, stored, and managed. As technology advances in areas such as AI, advanced energy storage, power conversion, and grid support, hybrid inverters will become more intelligent, efficient, and versatile. These improvements will drive the widespread adoption of renewable energy, support grid stability, and enhance energy independence for individuals, businesses, and communities. Hybrid inverters will continue to play a crucial role in creating a more sustainable, reliable, and cost-effective energy future, helping to accelerate the transition towards a cleaner, more resilient energy .

REFERENCES

- [1] J. Parikh, K. Parikh, "Growing Pains: Meeting India's Energy Needs in the Face of Limited Fossil Fuels," *IEEE Power Energy Mag.*, vol. 10, no. 3, pp. 59-66, June 2012.
- [2] R. Kadri, J. Gaubert, G. Champenois, "An Improved Maximum Power Point Tracking for Photovoltaic Grid-Connected Inverter Based on Voltage-Oriented Control," *IEEE Trans. Ind. Electron.*, vol. 58, no. 1, pp. 66-75, Jan. 2011.
- [3] B. Singh, M. Kandpal, I. Hussain, "Control of Grid Tied Smart PVDSTATCOM System Using an Adaptive Technique," *IEEE Trans. Smart Grid*, vol. 9, no. 5, pp. 3986-3993, Sept. 2018.
- [4] N. Kumar, B. Singh, B. K. Panigrahi, "LLMLF based Control Approach and LPO MPPT Technique for Improving Performance of a Multifunctional Three-Phase Two-Stage Grid Integrated PV System," *IEEE Trans. Sustain. Energy*, doi: 10.1109/TSTE.2019.2891558.
- [5] N. R. Tummuru, M. K. Mishra, S. Srinivas, "Multifunctional VSC Controlled Microgrid Using Instantaneous Symmetrical Components Theory," *IEEE Trans. Sustain. Energy*, vol. 5, no. 1, pp. 313-322, Jan. 2014.
- [6] N. Mahmud, A. Zahedi and A. Mahmud, "A Cooperative Operation of Novel PV Inverter Control Scheme and Storage Energy Management System Based on ANFIS for Voltage Regulation of Grid-Tied PV System," *IEEE Trans. Ind. Informat.*, vol. 13, no. 5, pp. 2657-2668, Oct 2017.
- [7] V. T. Tran, K. M. Muttaqi, D. Sutanto, "A Robust Power Management Strategy With Multi-Mode Control Features for an Integrated PV and Energy Storage System to Take the Advantage of ToU Electricity Pricing," *IEEE Trans. Ind. Appl.*, vol. 55, no. 2, pp. 2110- 2120, April 2019.
- [8] L. B. G. Campanhol, S. A. O. da Silva, A. A. de Oliveira, V. D. Bacon, "Single- Stage Three-Phase Grid-Tied PV System With Universal Filtering Capability Applied to DG Systems and AC Microgrids," *IEEE Trans. Power Electron.*, vol. 32, no. 12, pp. 9131-9142, Dec. 2017.
- [9] A. Yazdani et al., "Modeling Guidelines and a Benchmark for Power System Simulation Studies of Three-Phase Single-Stage Photovoltaic Systems," *IEEE Trans. Power Del.*, vol. 26, no. 2, pp. 1247-1264, April 2011. 42
- [10] P. Shah, I. Hussain, B. Singh, A. Chandra, K. Al-Haddad, "GI-Based Control Scheme for Single-Stage Grid Interfaced SECS for Power Quality Improvement," *IEEE Trans. Ind. Appl.*, vol. 55, no. 1, pp. 869- 881, Feb 2019.
- [11] S. Pradhan, I. Hussain, B. Singh, B. Ketan Panigrahi, "Performance Improvement of Grid-Integrated Solar PV System Using DNLMS Control Algorithm," *IEEE Trans. Ind. Appl.*, vol. 55, no. 1, pp. 78-91, Feb 2019.
- [12] V. Jain, B. Singh, "A Multiple Improved Notch Filter-Based Control for a Single- Stage PV System Tied to a Weak Grid," *IEEE Trans. Sustain. Energy*, vol. 10, no. 1, pp. 238- 247, Jan 2019.
- [13] Denholm P, Margolis RM, "Evaluating the limits of solar photovoltaics (PV) in electric power systems utilizing energy storage and other enabling technologies," *Energy Policy*, vol. 35, no. 9, pp. 4424-4433, Sept. 2007.
- [14] S. Roy Ghatak, S. Sannigrahi, P. Acharjee, "Optimised planning of distribution network with photovoltaic system, battery storage, and DSTATCOM," *IET Renewable Power Generation*, vol. 12, no. 15, pp. 1823-1832, 2018.
- [15] N. Korada and M. K. Mishra, "Grid Adaptive Power Management Strategy for an Integrated Microgrid With Hybrid Energy Storage," *IEEE Trans. Ind. Electron.*, vol. 64, no. 4, pp. 2884-2892, April 2017.



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