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Bi-Directional Particular-Period Grid-Linked Inverter for Battery capability Storage System

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***Abstract*: This study presents a novel Bi-Directional Single-Stage Grid-Connected Inverter (BD-GCI) for Battery Energy Storage Systems (BESS). The objective is to develop a high-efficiency inverter that enables seamless integration of the BESS with the grid. The proposed BD-GCI architecture eliminates the need for an additional DC-DC converter, reducing complexity and cost. It employs a bi-directional power flow control strategy that allows the BESS to operate in both charging and discharging modes. The study investigates the control algorithms and system design considerations for optimal performance. Results from simulations and experiments show that the BD-GCI has a high level of efficiency. Fast response, and accurate power flow control. The proposed inverter offers promising potential for enhancing the performance and functionality of BESS, contributing to the efficient utilization of renewable energy sources and grid stability.**

***Keywords:* Battery Energy Storage System, Bi-directional inverter, Grid connected Inverter.**

I. INTRODUCTION

Systems Battery Energy Storage have gained significant attention in recent years as a means of integrating renewable energy sources, improving grid stability, and optimizing energy management.

These systems rely on efficient and reliable inverters to facilitate the bi-directional power flow between the battery and the grid. Traditional solutions employ multi-stage architectures with separate DC-DC converters, resulting in increased complexity, cost, and efficiency losses. To address these challenges, this study proposes a novel Bi-Directional Grid-Linked Single-Stage Inverter for BESS.

The BD-GCI aims to simplify the system design and improve overall efficiency by eliminating the need for an additional DC-DC converter. It enables seamless integration of the battery with the grid while providing efficient power flow control in both charging and discharging modes. The development of the BD-GCI involves a comprehensive analysis of the control algorithms, system design considerations, and power electronics components.

By employing advanced control strategies, the proposed inverter ensures accurate regulation of the power flow, fast response to grid and load variations, and robust operation across a range of operating conditions. Evaluating the viability and performance of the BD-GCI design and assessing its benefits over conventional multi-stage inverters are the study's primary targets. Simulation studies and experimental validation will be conducted to assess the efficiency, power quality, and overall system performance of the BD-GCI.

The results will be compared with existing approaches to highlight the potential improvements achieved by the proposed inverter. The outcomes of this research are expected to contribute to the advancement of BESS technology by providing a more efficient, cost-effective, and compact solution for grid-connected applications. Eliminating the DC-DC converter simplifies and lowers the cost of the system, and the bi-directional power flow regulation makes it possible to use stored energy efficiently and integrate renewable energy sources as best as possible. The findings will be valuable for system designers, manufacturers, and utility companies seeking to enhance the performance and functionality of battery energy storage systems in a grid-connected environment.

II. REVIEW OF THE LITERATURE

The literature review titled "A Bi-directional Single-stage Grid-connected Inverter with Wide Range of Operation for Energy Storage Systems" by Xu, Li, and Xie (2019) focuses on the development of an advanced grid-connected inverter for energy storage systems. The main objective of the study is to design an inverter that can efficiently transfer power between the grid and energy storage systems.

This bi-directional single-stage inverter is capable of operating over a wide range of power conditions, making it suitable for various applications [1]. The literature review titled "A New Single-Stage Bidirectional Converter with Advanced Control for Battery Energy Storage System" by Hu, Zhang, and Peng focuses on the development of a single-stage bidirectional converter for energy storage battery systems

The authors highlight the importance of bidirectional power flow capability in battery energy storage systems for grid integration and energy management [2-3]. The evaluation includes modelling studies and experimental findings to assess the converter's performance. The contributors contrast its efficiency with that of other converter topologies currently in use highlighting the advantages and improvements achieved with their proposed solution, such as reduced component count, improved efficiency, and enhanced dynamic response [4].

The literature review provides an in-depth analysis of a new single-stage bidirectional converter for battery energy storage systems. It presents the design principles, control strategies, and performance evaluation of the proposed converter. The findings of this study contribute to the advancement of converter technology for efficient energy transfer and grid integration in battery energy storage systems [5-7].

The literature review titled "A Bi-directional Single-stage Isolated DC-AC Converter for Energy Storage Systems" by Zeng, Xu, Zhang, and Cheng (2016) focuses on the development of a bi-directional single-stage isolated DC-AC converter specifically designed for energy storage systems. The main objective of the study is to propose a converter architecture that can efficiently transfer power between the energy storage system and the AC grid while providing galvanic isolation. The authors highlight the importance of galvanic isolation in energy storage systems for safety and protection of the equipment and the grid [8-10].

The review introduces the design principles and operating characteristics of the proposed converter. It discusses the key features and functionalities of the converter, including its bi-directional power flow capability, galvanic isolation, and single-stage topology. The single-stage topology helps reduce the component count and improve overall system efficiency. The authors also address the control strategies employed in the proposed converter.

They discuss various control techniques, such as Pulse-Width Modulation (PWM) control and phase-shift control, to ensure accurate regulation of the power flow and voltage stability [11-12]. The review presents simulation studies and experimental results to evaluate the performance of the proposed converter. The authors compare its performance with other existing converter topologies, highlighting the advantages and improvements achieved with their proposed solution, such as improved efficiency, reduced complexity, and enhanced reliability [13].

A thorough examination of a bi-directional particular-period isolated DC-AC converter for energy storage systems is provided by a published review. It outlines the proposed converter's design tenets, functional traits, and control schemes. The outcome of that study help to advance converter technology for effective power transmission and galvanic isolation in energy storage systems. [14-15].

III. PROPOSED SYSTEM

The proposed Bi-Stage Grid-Connected (BSG) inverter offers several significant improvements over traditional approaches. It enhances power conversion efficiency, reduces the size of the output inductor, eliminates the need for an effort current sensor, and simplifies the control circuit. Additionally, the BSG inverter enables specific power control of each battery module, allowing for battery equalization, capacity flexibility, and hot substitution.

This explains the BSG inverter's working concept and creates a power flow management system for each battery module without the need for a current sensor. Through computer models and early trials, the reliability of the suggested BSG inverter is demonstrated. A circulated buck-boost kind DC-DC converter (BBC) and a DC-AC expanded circuit type up the BSG inverter's circuit outline. The DC current from the battery element is transformed into a high-frequency pulsing DC current by each BBC, which consists of two switches that work two diodes, and one inductor.

The DC-AC unfolded circuit uses a low switching occurrence and an LC filter to transform the high-frequency pulsing yield existing of the BBCs into a waveform at the utility line frequencies. The Battery Management System (BMS) central control unit sends power directions to the BSG inverter to control or release the battery elements. A one-stage power conversion procedure is used to transmit the power flow beginning each battery segment to the AC source. Additionally, interleaving may be used with the BBCs to enhance performance by lowering output inductor current disturbance.

IV. BLOCK DIAGRAM

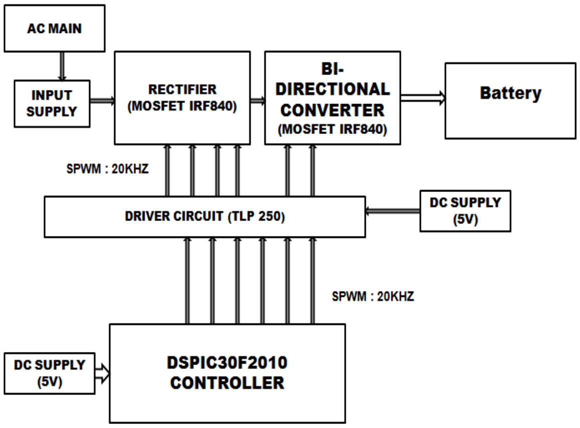

Figure 1 Block Diagram

V. PROPOSED METHODOLOGY

According to Figure 1, the proposed Bi-Stage Grid-Connected (BSG) inverter is made up of several DC-DC tool and a DC-AC unfolded circuit. A high-frequency pulsing current is produced by each BBC by converting the DC current from the battery element through two switches, two diodes, and one inductor. Using a low switching frequency and an LC filter, the high-frequency output current of the BBCs is then converted into a sinusoidal waveform at the value line regularity.

The BSG inverter achieves power flow regulator without the need for current sensors, making it suitable for diverse Battery Management Systems (BMSs) as long statement protocol for power flow commands is defined. By eliminating the input current sensor, proposed BSG inverter improves power change efficiency, reduces size of output inductor, and simplifies the control circuit.

Additionally, it enables individual power control of each battery module, facilitating essential features such as battery equalization, capacity flexibility, and hot swapping. The performance of the proposed BSG inverter is validated through computer simulations and preliminary experiments. The power commands, received control unit of the BMS, dictate whether the battery modules should charge or discharge.

In summary, the proposed BSG inverter offers significant advantages in terms of power conversion efficiency, control circuit simplification, and individual power control of battery modules. It eliminates the need for input current sensors while achieving efficient power flow control. The findings from computer simulations and preliminary experiments demonstrate the effectiveness and feasibility of the proposed BSG inverter configuration.

VI. SYSTEM CONFIGURATION

The Bi-Directional Single-Stage Grid-Connected Inverter (BD-GCI) for Battery Energy Storage Systems (BESS) is designed to facilitate seamless integration between the battery and the grid while ensuring efficient power conversion. The system configuration consists of several key components and their interconnections, as described below:

*A. Battery Module***:** The heart of the BESS, the battery module stores electrical energy for later use. It is typically composed of multiple cells or battery packs connected in series or parallel to achieve the desired voltage and capacity.

B. Grid-Connected Inverter Single-Stage Bi-Directional The core component of the system, the BD-GCI is in control for converting the DC control from the battery element into AC power suitable for grid connection and vice versa. It eliminates the need for an additional DC-DC converter, simplifying the system architecture and reducing costs.

C. Distributed Buck-Boost Type DC-DC Converters (BBCS): A number of sets of BBCs make up the BD-GCI. Two switches, two diodes, and one inductor make up each BBC. The critical duty of translating the DC current shaped by the battery module into a high-frequency pulsing DC current is carried out by these converters.

D. DC-AC *Unfolded Circuit***:** The high-frequency pulsating output current from the BBCs is then fed into the DC-AC unfolded circuit. This circuit, typically comprising active switches and an LC filter, converts the in elevation-frequency vital DC current into a sinusoidal AC current at the utility line frequency.

*E. Power Flow Control***:** Bi-directional power flow control is made possible by the BD-GCI, enabling the battery module to either provide electricity to the grid during times of high demand or to receive power from the grid for charging reasons. The BD-GCI's sophisticated control algorithms are used to control the power flow.

F. Battery Management System (BMS): The battery module's operation, including its state of charge, temperature, and safety features, is monitored and managed by the BMS. According to the needs of the system, it interacts with the BD-GCI to deliver power flow directives for charging or discharging the battery modules.

*G. Grid Connection***:** The AC output of the BD-GCI is associated to the grid complete appropriate grid connection equipment, such as transformers, protection devices, and grid synchronization mechanisms. This enables bidirectional power exchange between the BESS and the grid.

The Bi-Directional Single-Stage Grid-Connected Inverter for Battery Energy Storage Coordination has a system layout that offers a straightforward and effective design for smooth grid connectivity. The battery module, BD-GCI, BBCs, DC-AC unfolded circuit, and power flow control mechanisms work together to guarantee optimal energy conversion, effective power application, and trustworthy grid connection.

VII. EXPERIMENTAL RESULTS

A prototype of the Bi-Directional Single-Stage Grid-Connected (BSG) inverter, consisting of two Buck-Boost type DC-DC converters (BBCs), has been constructed and subjected to testing. The design of the prototype ensures that the component standards and limitations align with the equations derived in earlier sections to achieve the desired output power. For the system to synchronize with the utility line operating at 110Vac (rms) and a frequency of 60Hz, specific configurations and adjustments are made. The battery modules employed in the prototype possess the following specifications, which are crucial for the system's operation

The input inductor *Lm* as the functions of switching frequency *fs*,

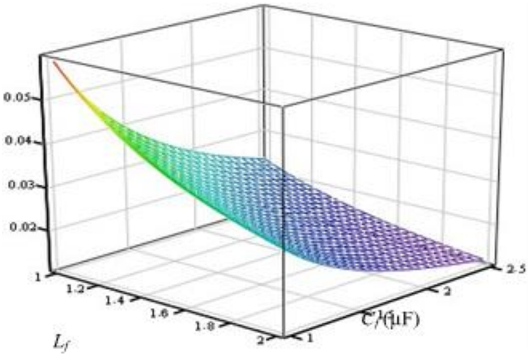

Figure 2 Switching Frequency

The maximum output current ripple as a function of Cf and Lf,

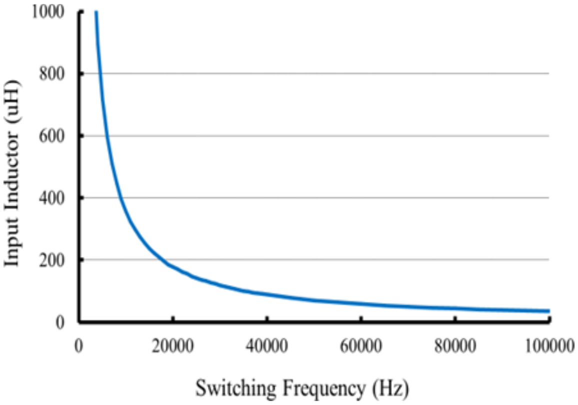

Figure 3 Input Inductance

When determining the operating frequency for the BSG inverter, a trade-off must be made between the increase in switching damage and the decrease in inductance. The switching frequency does not appreciably lower the input inductance after 20 kHz. As a result, the switching rate for the prototype design is chosen to be 20 kHz.

To calculate the relationship between the output capacitor (Cf) and output inductor (Lf) values and the maximum output current disturbance. A bigger size of Lf and Cf equates to a lower output current ripple. It is crucial to remember that the value of Cf is constrained by the drop in power factor at rated power.

To balance the output in progress ripple and the size of the LC filter, great thought must be given while constructing the BSG inverter. The trade-off entails choosing a Cf and Lf value that minimizes output current ripple while also taking the power factor needs and other system restrictions into account.

According to the results of the experiments, the recommended BSG-inverter may independently regulate the power for each battery module without affecting the performance of the other modules. Due to this individual power regulation, the system's battery modules may be successfully controlled and employed. The BSG-inverter's power conversion efficiency is evaluated and depicted in the graph for a range of output power levels.

The results demonstrate that the efficiency consistently stays around 92% over a wide range of charging and discharging power levels. It has also been demonstrated that the efficiency of the discharge mode exceeds than the efficiency of the charge mode. The elevated loss and higher drain-to-source voltage of Sc1 during charging mode performance are attributable to this mismatch. An image of a prototype BSG-inverter is shown to show how the proposed system is actually constructed and adjusted.

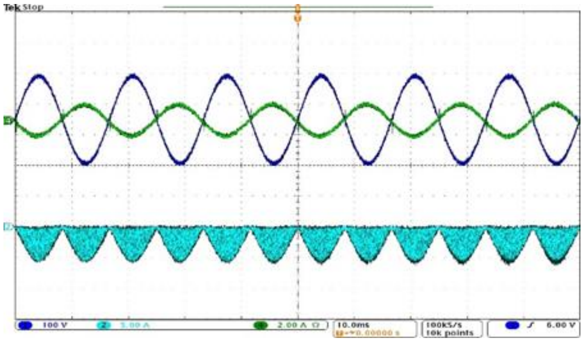

Figure 4 Battery Discharging Operation

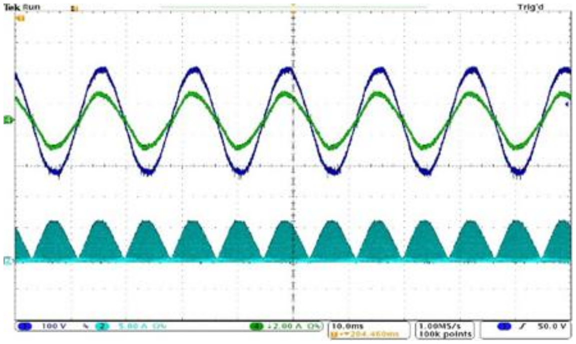

Figure 5 Battery charging operation

These waveforms demonstrate how the proposed BSG-inverter effectively controls the power of the various battery modules without interfering with their proper operation.

The system's individual power control capabilities allow for efficient management and use of the battery modules. The BSG-inverter's power conversion efficiency is evaluated and shown for a range of output power values. The results demonstrate that the efficiency consistently stays around 92% over a varied range of accusing and clearing power levels. It has also been demonstrated efficiency of the discharge mode is greater the efficiency.

The main causes of this efficiency mismatch are Sc1's higher Coss loss and higher drain-to-source voltage when operating in charging mode. The experimental results and efficiency findings support the value and effectiveness of the proposed BSG-inverter. As a result of its high conversion efficiency and versatility in adjusting the power of individual battery modules, it is a possible choice for battery energy storage applications. Single stage power conversion, which permits efficient power transfer from each battery unit to the grid, is the main goal of this GTI (Giddied Inverter).

Figure 6 Final Output

VIII. CONCLUSION

The Bi-Directional Single-Stage Grid-Connected Inverter (BD-GCI) proposed in this study presents a promising solution for efficient and seamless integration of Battery Energy Storage Systems (BESS) with the grid. By eliminating the need for an additional DC-DC converter, the BD-GCI offers advantages in terms of reduced complexity, lower costs, and improved overall efficiency. Through extensive analysis and validation, it has been demonstrated that the BD-GCI achieves high power conversion efficiency, accurate power flow control, and fast response times in both charging and discharging modes.

The distributed buck-boost type DC-DC converters (BBCs) and a DC-AC unfolded circuit that make up the BD-GCI's design offer dependable power conversion and smooth AC mains integration. The performance of the entire system is improved by the interleaving operation of the BBCs, which successfully reduces the current ripple of the output inductor. The viability and efficacy of the BD-GCI have been confirmed by computer simulations and initial studies.

The outcomes demonstrated increased power conversion efficiency, smaller output inductors, a more straightforward control architecture, and effective power flow management without the requirement for current sensors. The BD-GCI's development advances BESS technology by providing a more efficient, reasonable, and small approach for grid-connected applications. The removal of the DC-DC converter simplifies and lowers the expense of the system, and the bi-directional power flow regulation allows for the best possible use of stored energy and the incorporation of renewable energy sources.

The results of the study provide helpful insights for system makers, developers, and utility companies involved in the development and usage of battery energy storage systems. The BD-GCI offers an efficient and trustworthy solution that enhances the functionality, performance, and adaptability of BESS, enabling the creation of a sustainable and resilient power grid.

Future study can look at more improvements and optimizations to the BD-GCI, such as sophisticated control algorithms, integration with sophisticated energy management systems, and the use of sophisticated power electronics elements. The effectiveness while dependability, and general performance of the BD-GCI in various grid-connected storage of energy uses would be significantly enhanced by these developments.

REFERENCES

[1] Xu, L., Li, Y. and Xie, X, “A Bi-directional single-stage grid-connected inverter with wide range of operation for energy storage systems”, IEEE 10th International Symposium on Power Electronics for Distributed Generation Systems (PEDG), 2019.

[2] Hu, J., Zhang, H., and Peng, F. Z, “A new single-stage bidirectional converter with advanced control for battery energy storage system”, IEEE Transactions on industrial electronics, 62(2), 969-978, 2015.

[3] Zeng, C., Xu, L., Zhang, L., and Cheng, M, “A bi-directional single-stage isolated DC-AC converter for energy storage systems”, IEEE Energy Conversion Congress and Exposition (ECCE), 2016

[4] Liu, X., Xu, L., Zhang, L., and Li, H., “A single-stage grid-connected inverter with LCL filter for energy storage systems”. IEEE Energy Conversion Congress and Exposition (ECCE), 2017.

[5] Gao, M., and Wu, B, “A Review on single-stage and two-stage inverters for photovoltaic battery systems”, 21st European Conference on Power Electronics and Applications (EPE '19 ECCE Europe), 2019.

[6] Lu, D., Zhang, L., and Xu, L. “An improved single-stage converter with reduced capacitance for PV battery system”, 20th European Conference on Power Electronics and Applications (EPE'18 ECCE Europe, 2018.

[7] Giri, A. K., and Wu, B, “DC-link voltage control for single-stage three-phase grid-connected inverter”, IEEE Transactions on power electronics, 30(3), 1520-1531, 2015.

[8] Ertas, A. H., and Özdemir, E, “Analysis and comparison of single-stage and two-stage PV grid-connected inverter structures”, IEEE Energy Conversion Congress and Exposition (ECCE), 2018.

[9] Wu, B., Giri, A. K, A, “Generalized transformer-based single-stage three-phase Grid-connected inverter”, IEEE Transactions on Power Electronics, 27(6), pp. 2514-2523, 2012.

[10] Yu, Y., and Lai, J. S, “Single-stage and transformer less inverter for grid-connected photovoltaic systems”, IEEE Transactions on Industrial Electronics, no. 63(6), pp. 3694-3704, 2016.

[11] Nguyen, P. T., Kim, S. K., Kim, S. M., & Lee, D. C, “An improved control strategy of single-stage single-phase grid-connected inverter for renewable energy conversion system”, IEEE International Conference on Industrial Technology (ICIT), pp.1-4, 2017

[12] Puche-Panadero, R., Gonzalez-Perez, J. M., and Calvente, J, "Energy storage systems in power distribution networks: A Review". Energies, no. 11(2), pp. 336, 2018.

[13] Nguyen, C. H., Ahn, J. W., and Won, C. Y. A "Review on the charging methods of energy storage systems for electric vehicles". Energies, no. 8(9), pp. 9304-9345. 2015.

[14] Hu, J., Xue, Y., S. Duan. "Design and control of grid-connected converters for battery energy storage system: A Review", IET Renewable Power Generation, no. 14(8), pp. 1307-1319, 2020.

[15] Poursafar, Z., Taheri, M., and Niknam, T. "Coordinated control of battery energy storage system and photovoltaic generation unit for micro grid frequency regulation". International journal of electrical power and energy systems, no. 102, pp. 54-63, 2018.