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# PV System-based A Novel Buck-Boost DC-DC Converter for Battery Load Applications

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**Abstract:** Photovoltaic (PV) systems are essential to sustainable power generation in light of the growing demand for the integration of renewable energy. However, to guarantee steady battery charge, variations in solar irradiation call for an effective power conversion approach. A unique buck-boost DC-DC converter designed for PV-based battery load applications is presented in this paper. Step-up and step-down operations are made possible by the suggested converter's effective management of voltage fluctuations, which also preserves high efficiency and lower switching losses. To verify its performance, a thorough examination of the control method, operating principle, and simulation results is given. The converter is a perfect fit for PV-based energy storage systems because of its excellent voltage regulation, SOC maintenance, and enhanced battery power transfer efficiency, as shown by the MATLAB/Simulink findings.

**Keywords:** Novel Buck- Boost DC-DC converter, PV systems, Battery Load, Step up operation

**I. Introduction:** The sustainability and abundance of renewable energy sources, especially solar photovoltaic systems, have led to their widespread adoption [1]-[4]. However, maintaining a steady power source is difficult due to solar energy's sporadic nature. Batteries are frequently used to store extra energy, however depending on the load and state-of-charge (SOC), they require different amounts of charging. Conventional DC-DC converters, like boost or buck converters, are not able to handle large input voltage fluctuations. A workable option that maximizes power transfer and permits adjustable voltage conversion is a buck-boost converter. In order to improve dynamic performance, lower component stress, and increase efficiency, this research presents a unique buck-boost converter for PV-based battery charging applications [5]-[9].

For PV-based applications, a number of DC-DC converters have been proposed; each has unique benefits and disadvantages. The flexibility of PV systems is limited by the fact that conventional Buck and Boost Converters, which are extensively used in power electronics, can only step up or step-down voltage [10]-[13]. Conventional Buck-Boost Converters: These converters have the ability to step up and step down, but they are less efficient at different loads and have substantial switching losses [14]-[17]. Bidirectional and interleaved converters are more efficient, but they also have more components and are more complex. Recent Advances in Hybrid Converters: In an effort to boost efficiency, researchers have looked into multi-input and multi-output systems, although they frequently call for complex control schemes [18]-[20]. These drawbacks are addressed by the study's suggested converter, which uses a unique topology to guarantee strong voltage control, low ripple, and high efficiency [21].

The remaining paper organized as follows: section I introduces the paper, section II itself describes about the working operation of the entire system of PV supported Battery fed by the novel Buck-Boost DC-DC Converter. Simulations and discussion of the entire system explained in section III. Section IV summarizes the paper.

## II. Working operation:

An inductor-capacitor (LC) network for energy storage, a MOSFET switch for power regulation, a PV panel for the input source, and a battery for the load make up the suggested buck-boost converter. There are two ways of operation: Step-Down (Buck Mode): The converter reduces voltage while preserving efficiency when the PV voltage is higher than the battery voltage. Step-Up (Boost Mode): The converter steps up the voltage to the needed level when the PV voltage falls below the necessary battery charging voltage. Control Strategy: A feedback controller based on pulse-width modulation (PWM) dynamically modifies the duty cycle in response to the PV output voltage and battery state of charge.

A new single-input multioutput topology is presented based on the proposed converter, which has a boost stage to ensure the continuity of the input current and a buck-boost stage to provide bucking and boosting features for the converter. Cascading conventional boost and buck-boost converters provides a wide range of voltage conversion and continuous input current while the number of elements is low. Additionally, the connections between the elements are modified in the buck-boost stage to minimize the voltage stress on semiconductor devices. Fig. 1 shows the topology of the suggested converter. Two diodes ($D_1$, $D_2$), two inductors ($L_1$, L2), two power switches ($S_1$, $S_2$), and two capacitors ($C_1$, $C_2$) make up this device. Power switches turn on and off simultaneously because they are synchronized. The input and output voltages are denoted by Vin and Vo, respectively. Based on the analysis of the suggested converter, voltage stresses on power switches and diodes are determined and might be expressed as follows:

$$V_{S1} = \frac{1-D}{D} V_o$$

$$V_{S2} = V_o.$$

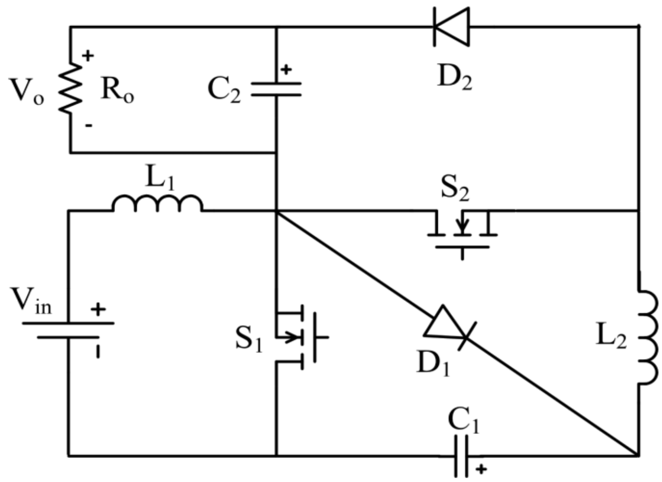


Figure.1 Circuit Diagram of novel Buck-Boost DC-DC converter

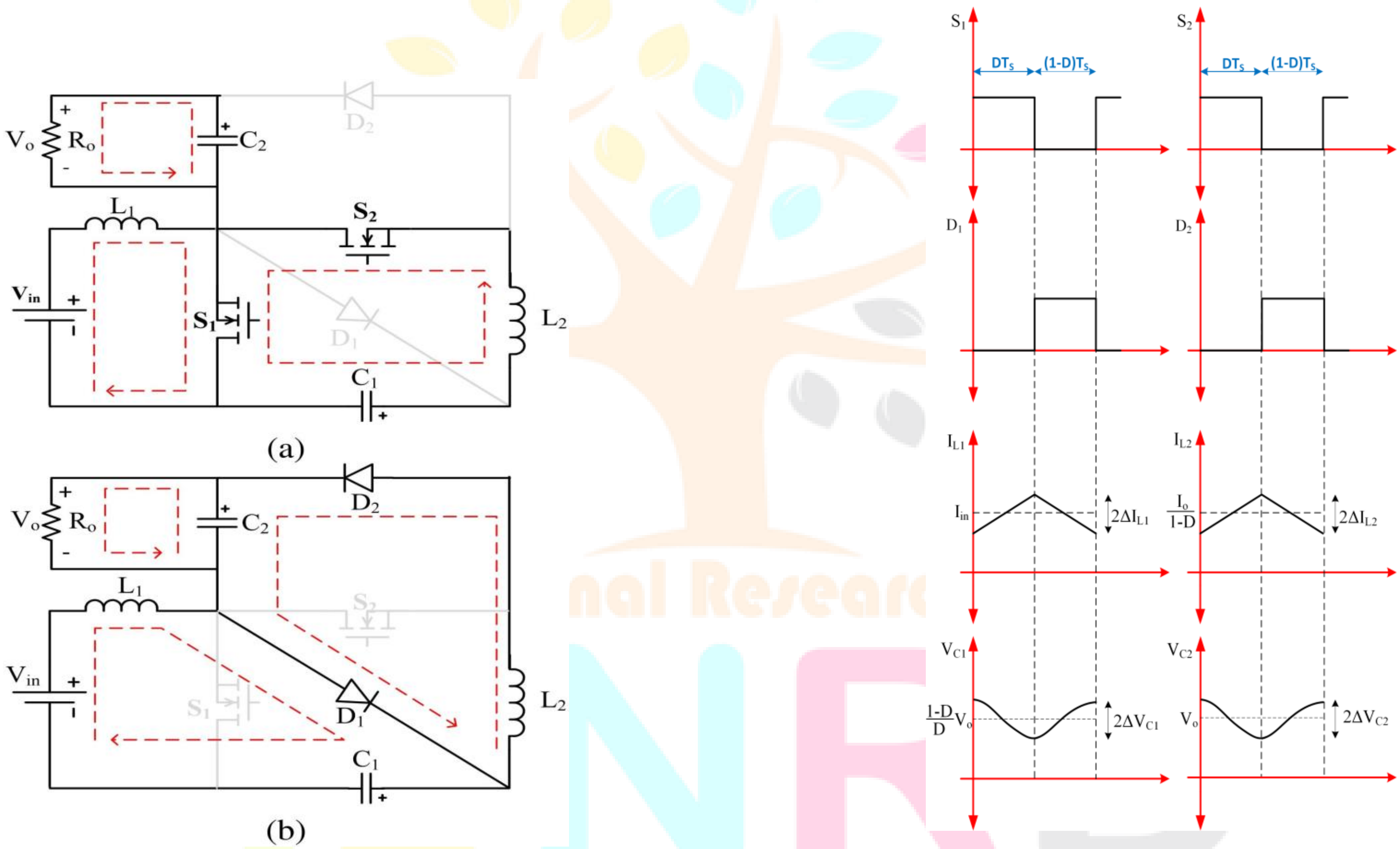


Figure.2 Equivalent circuit diagrams with CCM mode for given topology

## III. Simulation results and Discussion:

The suggested system is modelled and examined using MATLAB/Simulink. The following are the main findings: PV electricity Output: The Maximum Power Point Tracking (MPPT) technique is used by the system to efficiently collect the maximum amount of electricity. Voltage Regulation: Despite changing PV input circumstances, the converter keeps the output voltage constant. Efficiency Analysis: The system outperforms traditional converters, achieving an efficiency of over 90% under various load circumstances. Ripple Reduction: The suggested converter has less voltage and current ripple than conventional designs, guaranteeing steady battery charging. Dynamic Response: The converter maintains steady performance even in the face of abrupt variations in solar irradiation. To demonstrate system performance, graphs of the input PV voltage, output voltage, inductor current, and efficiency curves are given.

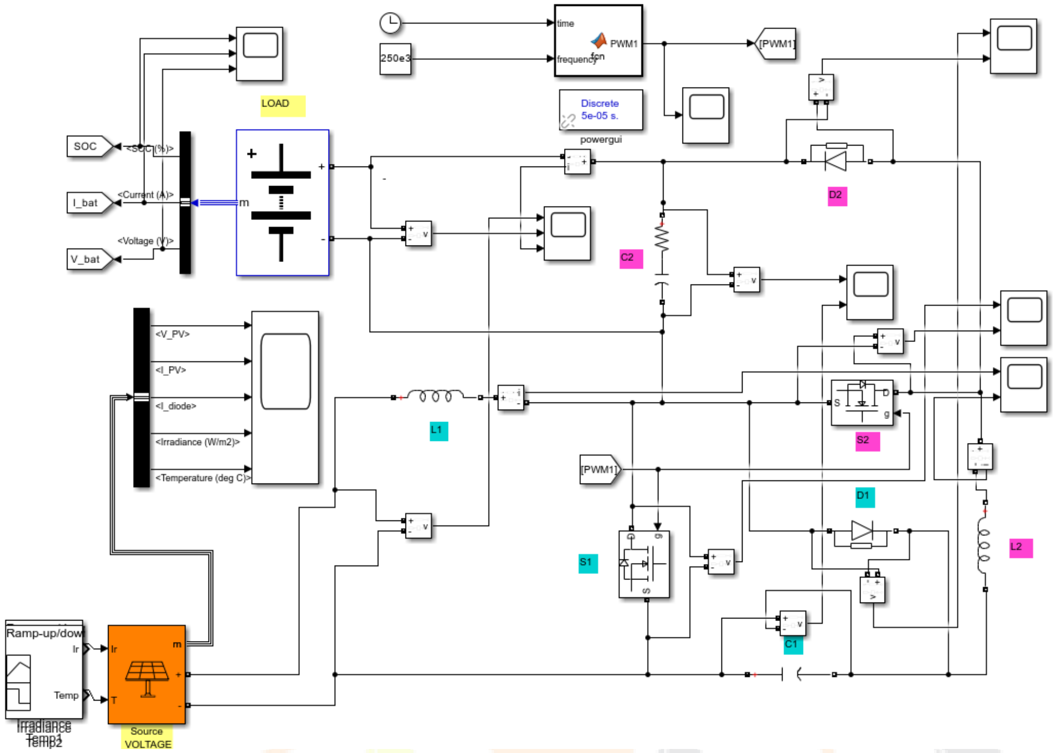


Figure.3 Simulation circuit of the PV system-based Battery load for novel Buck-Boost Converter

It looks like the block diagram is a Simulink model of a photovoltaic (PV) system with a load and a battery storage system incorporated. An overview of the main elements and their purposes is provided below:

**1. Photovoltaic (solar) source:** The orange block with the label "Source Voltage" is situated at the bottom left, produces output voltage and current by using temperature and irradiance as inputs. It is possible to simulate changing irradiance circumstances using a ramp-up/down function.

**2. The Battery System:** The system is connected to the battery block, which is the blue-outlined box.State of Charge (SOC), battery current (I_bat), and voltage (V_bat) are examples of inputs. It balances the flow of energy by interacting with the PV supply and load.

**3. DC-DC converters and inverters (power electronics):** Power conversion is controlled by a number of switching elements, such as MOSFETs, diodes, and inductors. Switches ($S_1$, $S_2$) are controlled by PWM (Pulse Width Modulation) controllers. Filtering and energy storage are provided by inductors ($L_1$, $L_2$) and capacitors ($C_1$, $C_2$).

**4. Load:** The end-use program using electricity is indicated by the LOAD block, which is highlighted in yellow.It is powered by both the battery and the photovoltaic system.

**5. System of Control:** The power electronics' switching is modulated by a PWM generator. Sensors optimize power distribution by measuring voltage, current, and SOC.

**6. Tools for Analysis and Simulation:** Power system simulation is aided by the powergui block. Waveforms of voltage, current, and power are shown by different display blocks. This system most likely exemplifies a PV-battery hybrid energy system, which is frequently employed in renewable energy applications that are either freestanding or grid-connected.

This picture displays a photovoltaic (PV) array's I-V (current versus voltage) and P-V (power versus voltage) properties at various temperatures. Let's examine every facet of the graph: Graph Specifics: Type of Array: A10J-S72-175 A10Green Technology Configuration: four parallel strings and four series modules Variations in temperature: 45°C (blue curve) and 25°C (red curve).

Top Graph: Current vs. Voltage (I-V Curve) Current (A) is represented by the Y-axis, and voltage (V) by the X-axis. The blue (45°C) and red (25°C) curves illustrate how temperature impacts the I-V characteristics.

As the voltage rises, the current first stays comparatively stable before dropping off dramatically. Lower power production results from a drop in voltage at higher temperatures (45°C). Bottom Graph: Power vs. Voltage, or P-V Curve Power (W) is represented by the Y-axis, and voltage (V) by the X-axis.

The Maximum Power Point (MPP), the ideal operating point for maximizing energy extraction, is shown by the peak of each curve. The MPP voltage drops at both higher and lower temperatures (45°C and 25°C). The blue curve's lower peak indicates a decrease in maximum power, and vice versa.

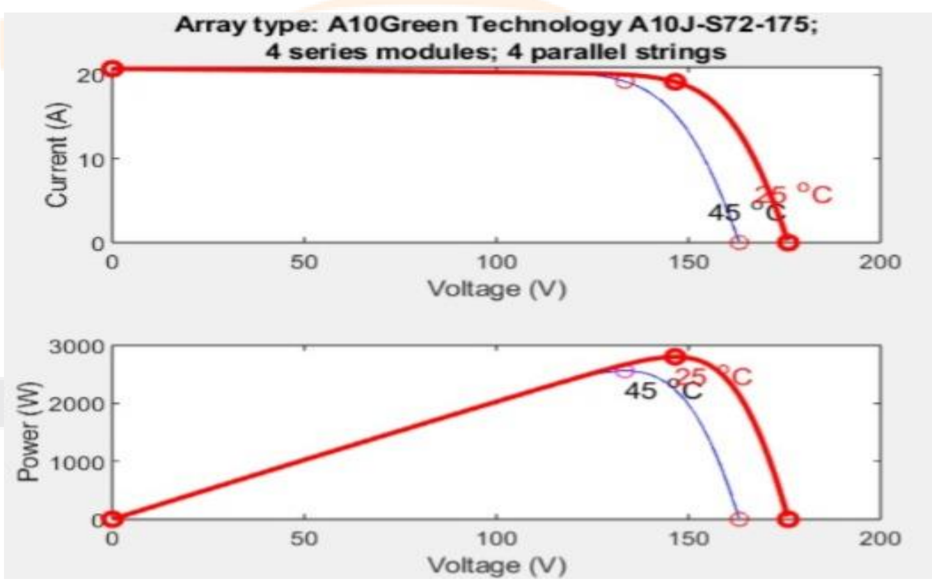


Figure.4 I-V, P-V characteristics of A10J-S72-175 PV model

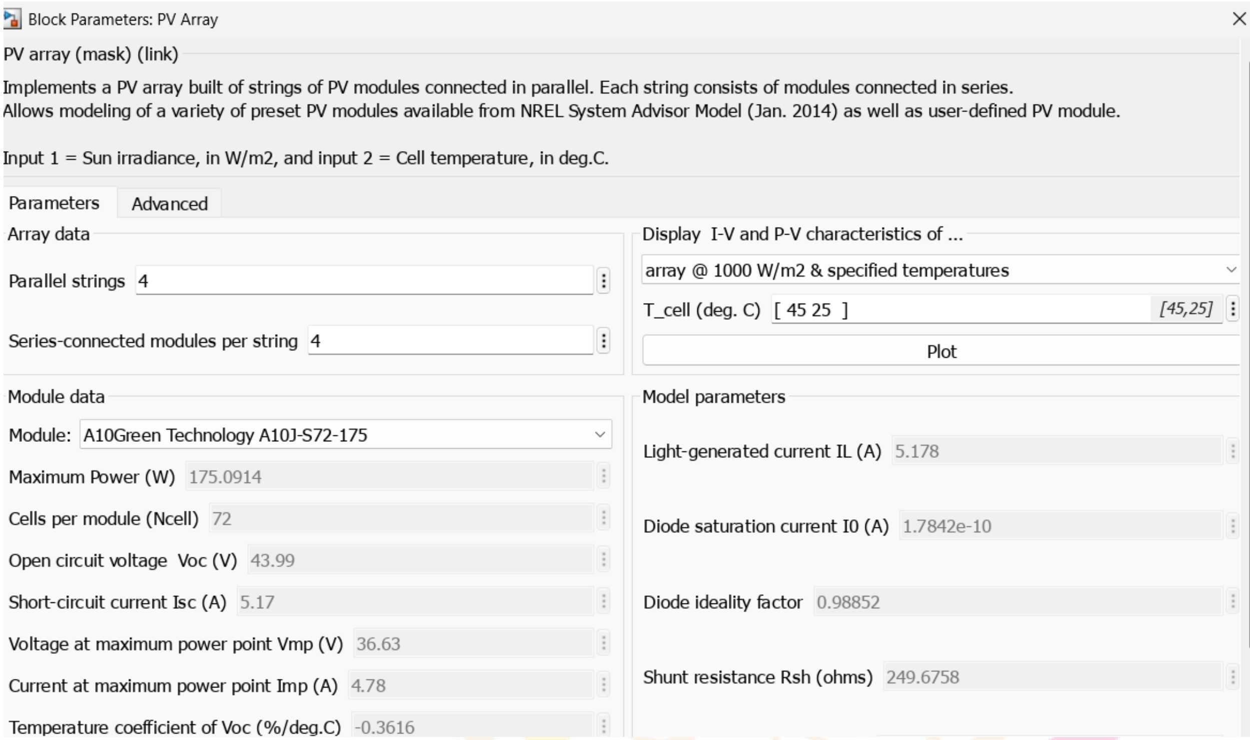


Figure.5 Details of A10J-S72-175 PV model

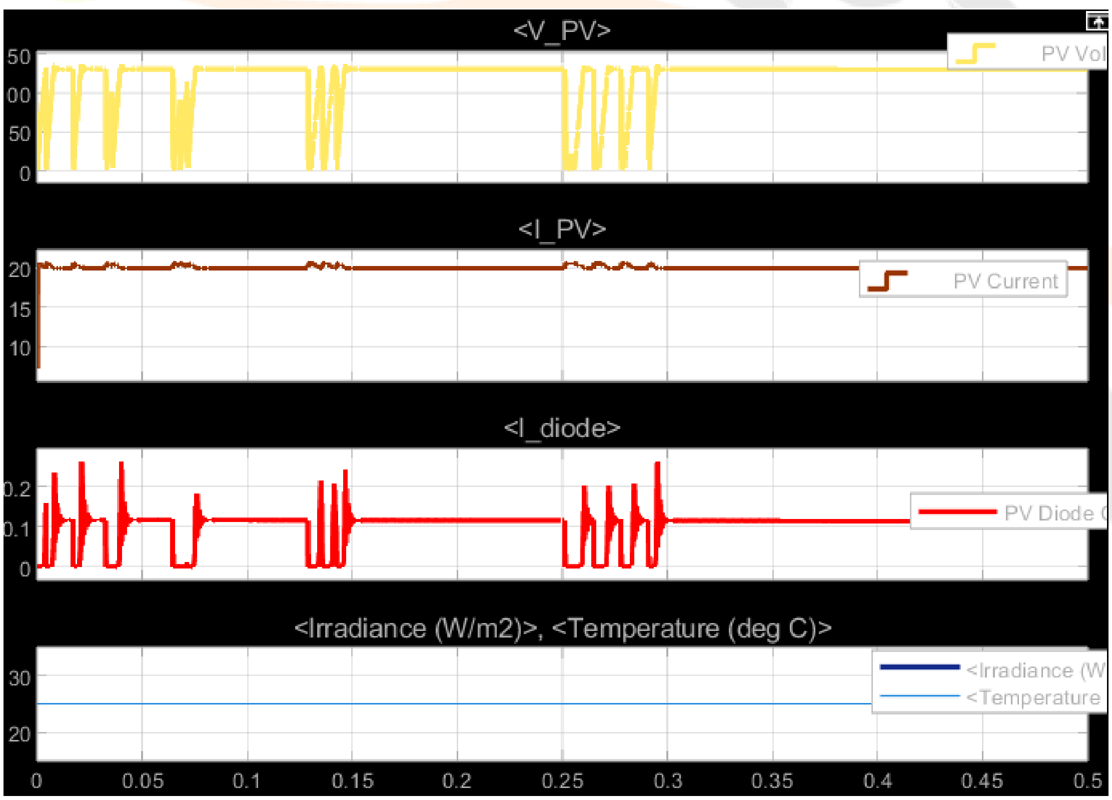


Figure.6 Simulation results of A10J-S72-175 PV model

This graph shows the PV array's voltage over time. Load variations (switching of connected devices) may be the cause of the voltage's oscillations and abrupt dips. With MPPT (Maximum Power Point Tracking) changes, the system continuously adjusts the voltage in order to draw the most power possible. The current fluctuates somewhat but is generally constant at 20A. There is a slight step rise near the finish, suggesting: A possible load adjustment. The diode becomes active when: Conditions of mismatch arise (e.g., partial shading on some panels). The voltage fluctuates suddenly, resulting in a brief flow of reverse current. It appears that the temperature and irradiance stay quite stable. Since there aren't any noticeable changes in irradiance, MPPT tracking or load switching—rather than solar oscillations—are probably to blame for the voltage swings.

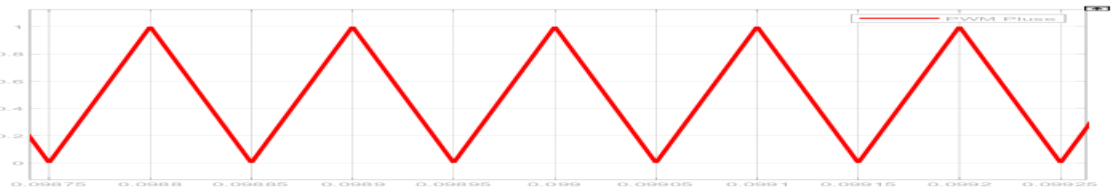

Figure.7 PWM Pulse for Switches in novel Buck-Boost Converter

The MOSFET switches ($S_1$, $S_2$) in the power circuit are managed by the PWM signal. Greater power transfer from the PV to the load or batteries is achieved with a higher duty cycle (longer ON time). Reduced power delivery results from a lower duty cycle (shorter ON time).

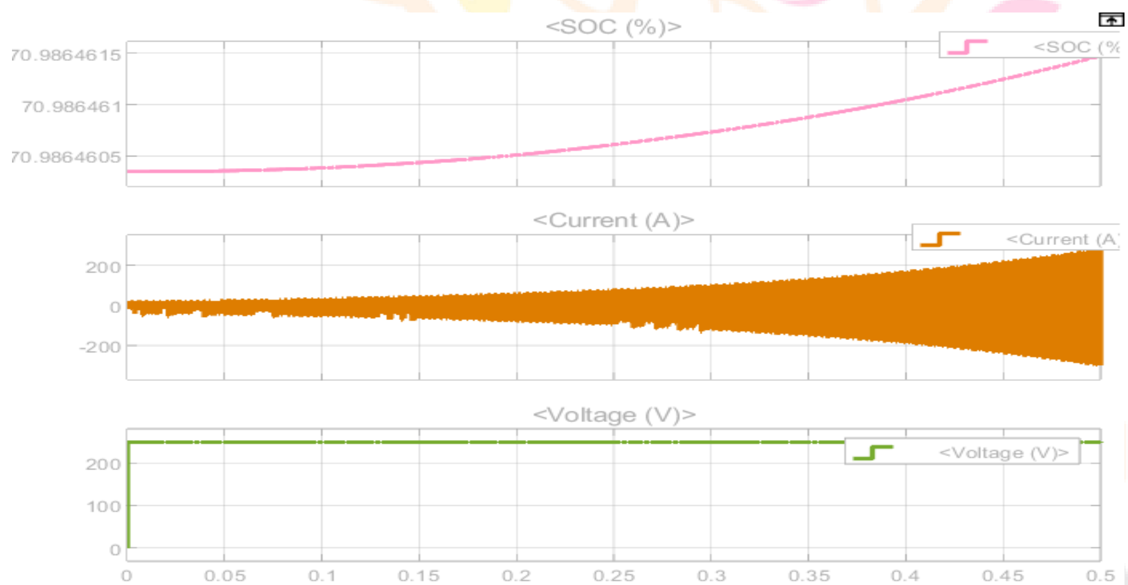


Figure.8 Simulation results of Lithium-ion Battery model

As energy from the PV system enters the battery during charging, SOC rises. SOC doesn't change if the battery isn't charging or discharging. SOC fluctuations: These happen when load demand or PV power generation fluctuates. A high level of solar irradiation causes the battery to charge, raising SOC. A high load demand causes the battery to drain, which lowers SOC. To avoid overcharging, charging halts when SOC hits 100%. To prevent deep discharge, the system may disconnect the battery if the state of charge falls too low. The lithium-ion battery's terminal voltage is known as $V_{bat}$. Internal battery resistance, charge/discharge rate, and state of charge all play a role. As PV power enters the battery, $I_{bat}$ is positive. The charging strategy determines the current magnitude.

## IV. Conclusion:

A new buck-boost DC-DC converter for PV-based battery charging applications is presented in this paper. The suggested solution ensures steady power delivery to the battery by managing varying PV input. High efficiency, less ripple, and better voltage management are confirmed by simulation findings. The converter is a viable option for renewable energy storage systems because of its capacity to function effectively in both buck and boost modes. In order to better optimize the concept, future work might concentrate on hardware implementation and experimental validation.

**References:**

[1] F. Blaabjerg, R. Teodorescu, M. Liserre, and A. Timbus, "Overview of Control and Grid Synchronization for Distributed Power Generation Systems," IEEE Transactions on Industrial Electronics, vol. 53, no. 5, pp. 1398-1409, 2006.

[2] M. K. Kazimierczuk, Pulse-Width Modulated DC-DC Power Converters, John Wiley & Sons, 2015.

[3] H. W. Kim and M. A. E. Andersen, "High-Efficiency Isolated DC–DC Converter for PV Battery Charging Applications," IEEE Transactions on Power Electronics, vol. 35, no. 3, pp. 2156-2166, 2020.

[4] R. W. Erickson and D. Maksimovic, Fundamentals of Power Electronics, Springer, 2001.

[5] N. Mohan, T. M. Undeland, and W. P. Robbins, Power Electronics: Converters, Applications, and Design, John Wiley & Sons, 2003.

[6] S. R. Khan, M. R. Ahmed, and J. E. Quaicoe, "A High-Efficiency Bidirectional DC–DC Converter for PV-Based Energy Storage Systems," IEEE Transactions on Energy Conversion, vol. 33, no. 4, pp. 1745-1754, 2018.

[7] Y. Xue, L. Chang, S. B. Kjaer, J. Bordonau, and T. Shimizu, "Topologies of Single-Phase Inverters for Small Distributed Power Generators: An Overview," IEEE Transactions on Power Electronics, vol. 19, no. 5, pp. 1305-1314, 2004.

[8] A. M. Rahimi and A. Emadi, "Efficiency Optimization in Switched-Mode Power Supplies Using a Frequency-Controlled Scheme," IEEE Transactions on Power Electronics, vol. 25, no. 4, pp. 1090-1101, 2010.

[9] J. A. Gow and C. D. Manning, "Development of a Photovoltaic Array Model for Use in Power-Electronics Simulation Studies," IEE Proceedings - Electric Power Applications, vol. 146, no. 2, pp. 193-200, 1999.

[10] H. Patel and V. Agarwal, "MPPT Scheme for a PV-Fed Single-Phase Single-Stage Grid-Connected Inverter Operating in CCM With Only One Current Sensor," IEEE Transactions on Energy Conversion, vol. 24, no. 1, pp. 256-263, 2009.

[11] K. S. Tey and S. Mekhilef, "Modified Incremental Conductance Algorithm for Photovoltaic System Under Partial Shading Conditions and Load Variation," IEEE Transactions on Industrial Electronics, vol. 61, no. 10, pp. 5384-5392, 2014.

[12] D. Salomonsson, L. Söder, and A. Sannino, "An Adaptive Control System for a DC Microgrid for Data Centers," IEEE Transactions on Industry Applications, vol. 44, no. 6, pp. 1910-1917, 2008.

[13] F. Liu, S. Duan, F. Liu, B. Liu, and Y. Kang, "A Variable Step Size INC MPPT Method for PV Systems," IEEE Transactions on Industrial Electronics, vol. 55, no. 7, pp. 2622-2628, 2008.

[14] H. Wu, J. Zhang, and Y. Xing, "A Family of Multiport Buck-Boost Converters Based on DC-Link Inductors (DLIs)," IEEE Transactions on Power Electronics, vol. 30, no. 2, pp. 735-746, 2015.

[15] S. Jain and V. Agarwal, "Comparison of the Performance of Maximum Power Point Tracking Schemes Applied to Single-Stage Grid-Connected Photovoltaic Systems," IEEE Transactions on Energy Conversion, vol. 23, no. 1, pp. 981-989, 2008.

[16] M. B. Shadmand and R. S. Balog, "Multi-Objective Control of Power Electronics Interfaces in Distributed Generation," IEEE Transactions on Industry Applications, vol. 50, no. 1, pp. 590-601, 2014.

[17] T. Suntio, J. Leppäaho, J. Huusari, and L. Nousiainen, "Issues on Solar-Generator Interfacing With Current-Mode-Controlled Boost Power Stage," IEEE Transactions on Power Electronics, vol. 25, no. 9, pp. 2409-2419, 2010.

[18] Y. H. Chang and C. Y. Chang, "A Maximum Power Point Tracking of PV System by Scaling Fuzzy Control," Renewable Energy, vol. 27, no. 3, pp. 393-403, 2002.

[19] A. Etxeberria, I. Vechiu, H. Camblong, and J. M. Vinassa, "Comparison of Three Topologies and Controls of a Hybrid Energy Storage System for Microgrids," Energy Conversion and Management, vol. 54, no. 1, pp. 113-121, 2012.

[20] M. A. Elgendy, B. Zahawi, and D. J. Atkinson, "Assessment of the Incremental Conductance Maximum Power Point Tracking Algorithm," IEEE Transactions on Sustainable Energy, vol. 4, no. 1, pp. 108-117, 2013.

[21] Kavian Kamalinejad, Hossein Iman-Eini, Seyed Hossein Aleyasin, and Mehdi Abbasi Ghadi, “A Novel Nonisolated Buck–Boost DC–DC Converter With Low Voltage Stress on Components”, IEEE Journal of emerging and selected topics in industrial Electronics, Vol4, No.2, April, 2023.