Simulation of PV-Battery Hybrid Power System in MATLAB/Simulink

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Software: MATLAB/Simulink R2024b
Electrical Project Repository: Link
Link Simulation Results: Link

1. Introduction

This project presents the design and simulation of a PV–Battery hybrid power system using MATLAB/Simulink. The model integrates a photovoltaic (PV) array, battery storage, and control mechanisms to maintain reliable DC bus voltage and optimize power flow under varying load and environmental conditions. Such hybrid systems form the backbone of modern renewable energy integration in smart grids and microgrids.

2. Objective

- To simulate a hybrid PV–Battery system for efficient power management.
- To implement Maximum Power Point Tracking (MPPT) using the Perturb and Observe method.
- To validate DC bus voltage and current regulation using PI controllers.
- To analyze scope outputs for voltage, current, and duty cycle variations.

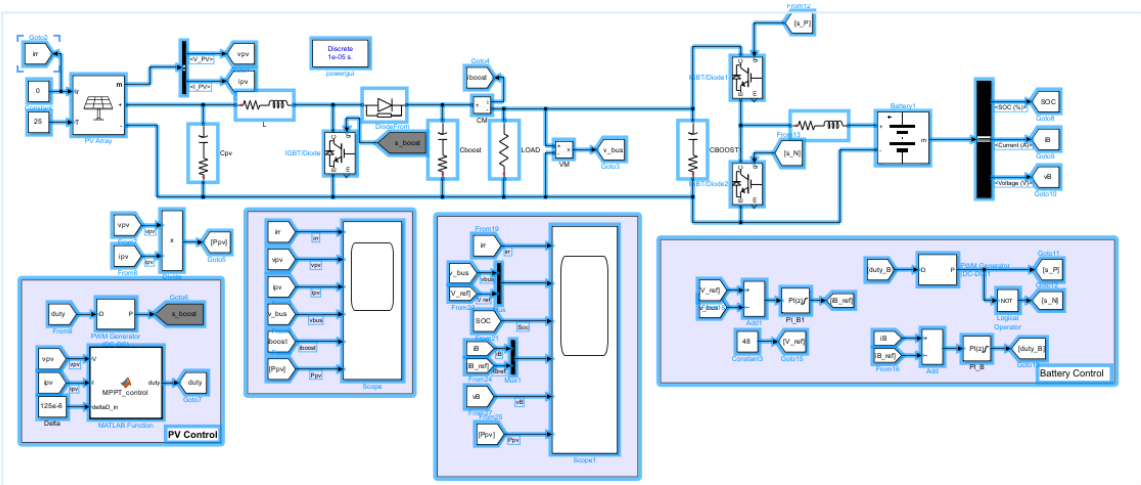

Figure 1: Block Diagram of PV–Battery Hybrid Power System

3. System Components

The hybrid system consists of the following major components:

• PV Array: 5 parallel strings, max power 213.15 W, Voc = 36.3 V, Isc = 7.84 A, Vmp = 29 V, Imp = 7.35 A.
• Battery: 24 V, 50 Ah Lithium-Ion battery with cutoff at 18 V, full charge at 27.9 V.
• DC–DC Converters: Controlled using PWM generators at 5 kHz switching frequency.
• PI Controllers: Tuned for bus voltage and current regulation.
• MPPT Algorithm: Implemented using a MATLAB function block (Perturb & Observe).

4. Methodology

The simulation model was developed in MATLAB/Simulink with the following methodology:

• Modeled PV, battery, converters, and control loops in Simulink.
• Applied PI-based control for Vbus and Ibus stability.
• Implemented MPPT to maximize PV power extraction.
• Simulated the system under different load and irradiation profiles.

5. Results & Key Observations

The simulation results are obtained from scope blocks and analyzed to evaluate system performance.

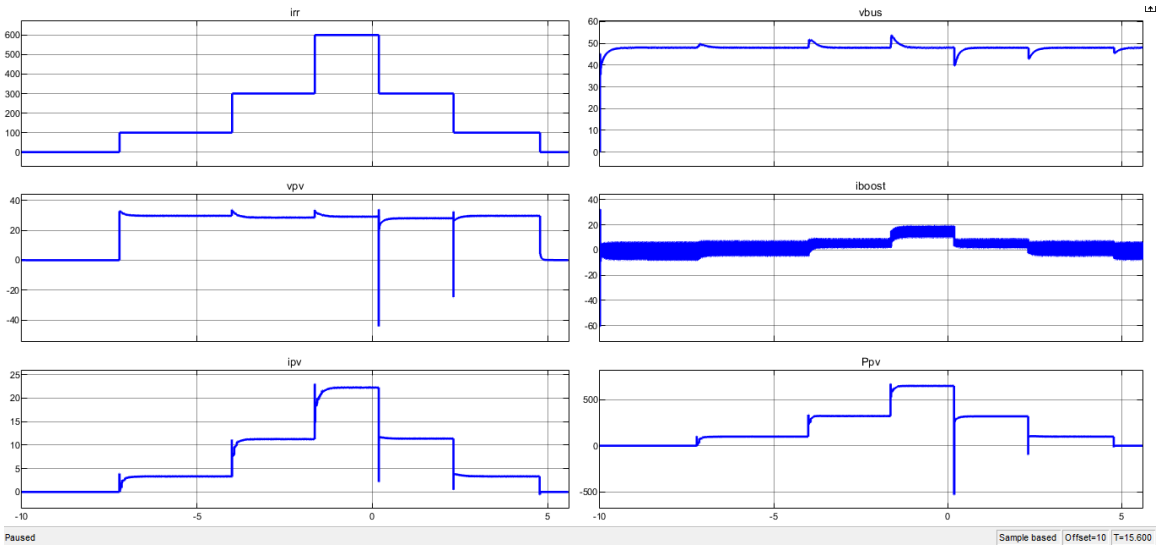

Figure 2: PV array voltage and current characteristics (Scope Output).

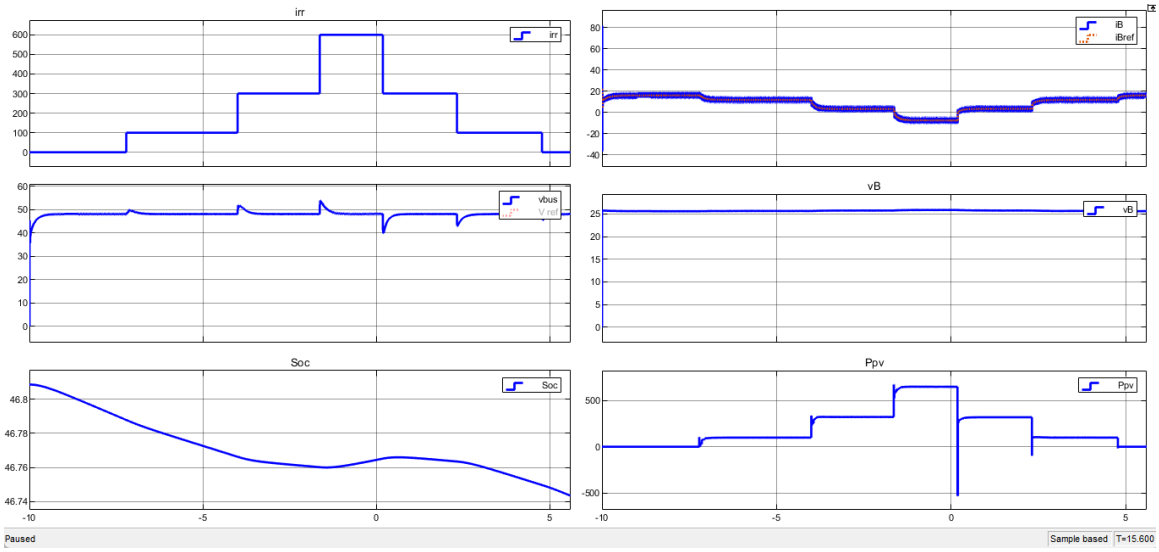

Figure 3: Battery charging/discharging response (Scope Output).

Figure 3: Overall system model in MATLAB/Simulink.

Key observations:
- The PV array output stabilizes at maximum power point under MPPT control.
- The battery compensates for load fluctuations, maintaining bus voltage.
- PI controllers ensure stable operation within defined upper/lower limits.

6. Conclusion

The PV–Battery hybrid power system simulation in MATLAB/Simulink demonstrates the effectiveness of renewable integration and energy storage management. The system maintains stable bus voltage, optimizes PV generation, and ensures smooth power flow. This validates its applicability for microgrid and distributed generation systems, providing a sustainable solution for future energy demands.

Appendix A: System Parameters and Controller Settings

Parameter	Value
PV Array	
Parallel strings	5
Series per string	1
Maximum power (W)	213.15
Cells per module	60
Voc (V)	36.3
Isc (A)	7.84
Vmp (V)	29
Imp (A)	7.35
Cell degree	45°

Battery	
Type	Lithium Ion
Nominal voltage (V)	24
Rated capacity (Ah)	50
Initial SOC (%)	45
Battery response time (s)	1
Cut-off Voltage (V)	18
Fully charged voltage (V)	27.9
Nominal discharge current (A)	21.7
Capacity (Ah) at nominal voltage	45.2
Exponential zone (V, Ah)	(25.9, 2.45)
PWM (PV control)	
Switching frequency (Hz)	5000
Sample time (s)	10e-6
PI (V_Bus)	
Controller	PI (Discrete)
Sample time (s)	500e-6
P	0.85
I	10
Upper limit	22
Lower limit	-22
PWM (Battery control)	
Switching frequency (Hz)	5000
Sample time (s)	10e-6
PI (I_Bus)	
Controller	PI (Discrete)
Sample time (s)	50e-6
P	0.01
I	10
Upper limit	0.95
Lower limit	0