BITS
Pilani

ENERGY STORAGE SYSTEMS F428

Hybrid Wind-PV-Battery Energy System for DC Load: Simulink Implementation

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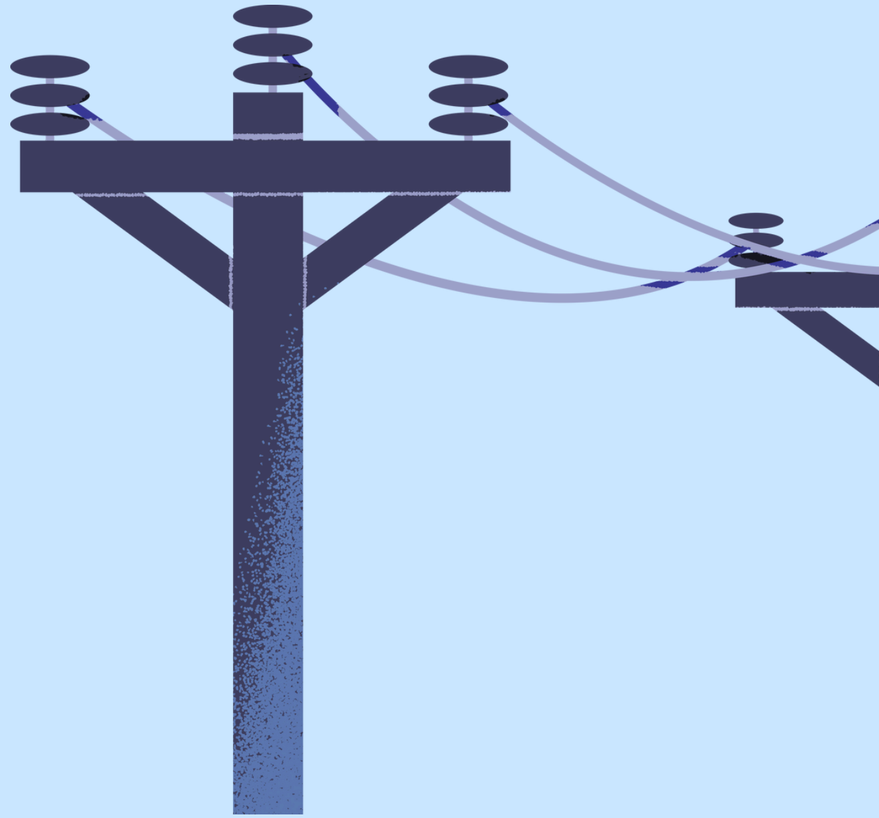
Background Information



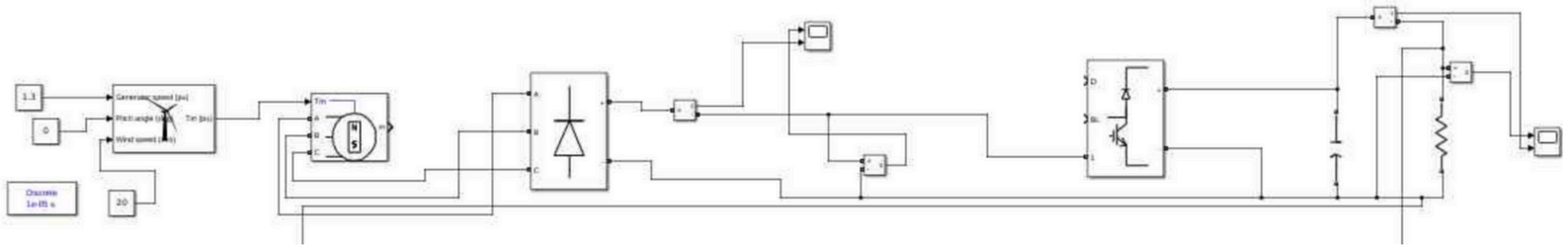
Hybrid energy systems combine solar PV, wind turbines, and batteries to ensure reliable power supply. Solar and wind complement each other, while the battery mitigates intermittency, enhancing efficiency and stability for continuous load support.

Objectives

- Design and Simulation: Develop a hybrid wind-solar-battery system for continuous power supply to a DC load.
- Energy Management: Optimize the use of renewable sources (wind and solar) and battery storage for efficient energy utilization.
- Stability and Reliability: Ensure stable DC bus voltage and continuous load supply under varying environmental conditions.
- System Integration: Integrate wind and solar energy sources with battery storage to enhance system efficiency and sustainability.

Components

1 Wind Turbine

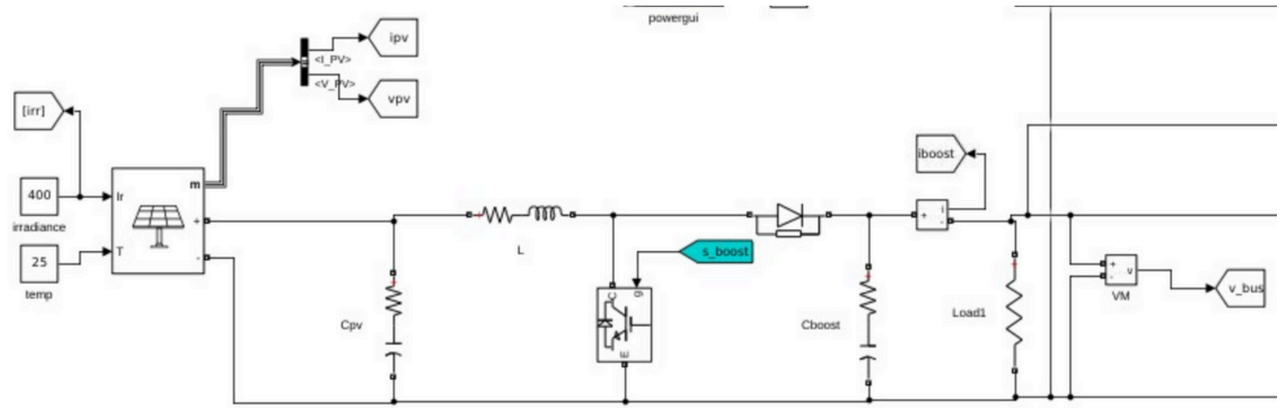


The wind turbine generates electrical power through PMSG based on wind speed.

The power is rectified and regulated to match the DC bus requirements through boost converter.

Components

2 Solar PV

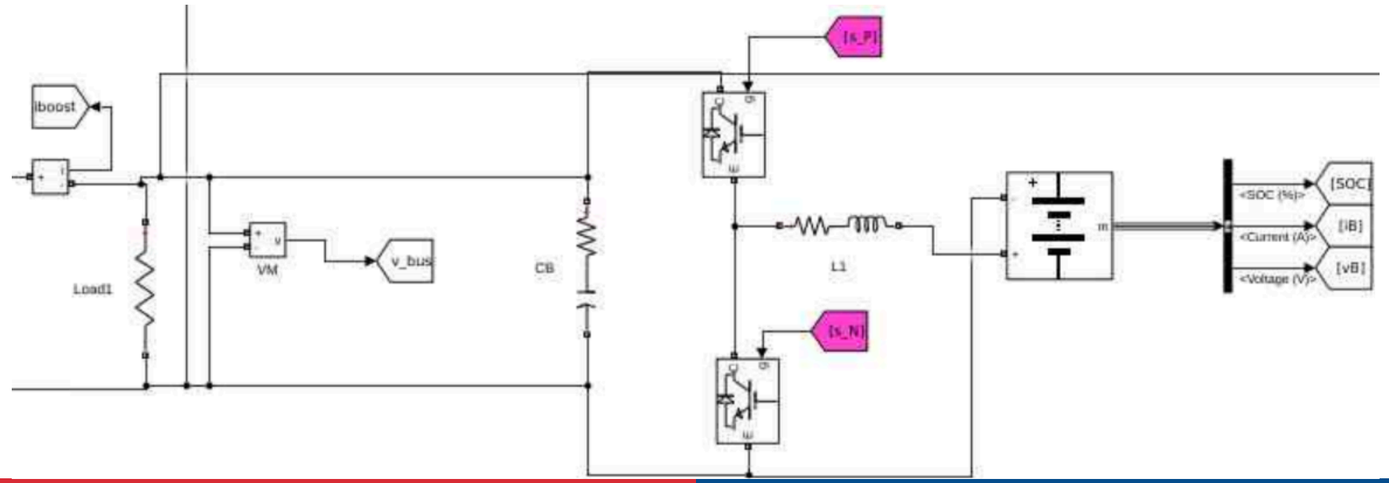


The PV system generates power based on solar irradiance levels.

MPPT is used to optimize the PV output. which is given to the load through boost converter.

Components

3 Battery

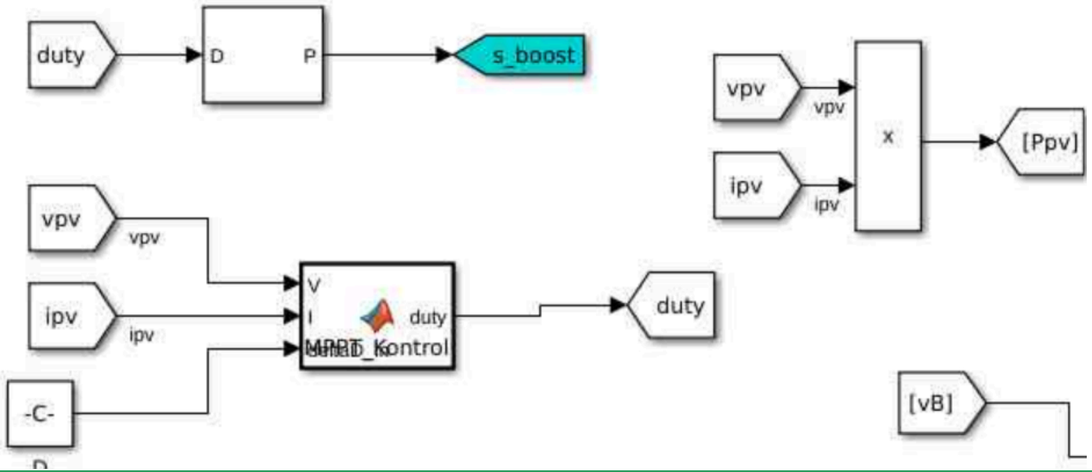


The battery charges during surplus generation and discharges during demand peaks or low generation.

This happens through a bi- directional converter.

Control Systems

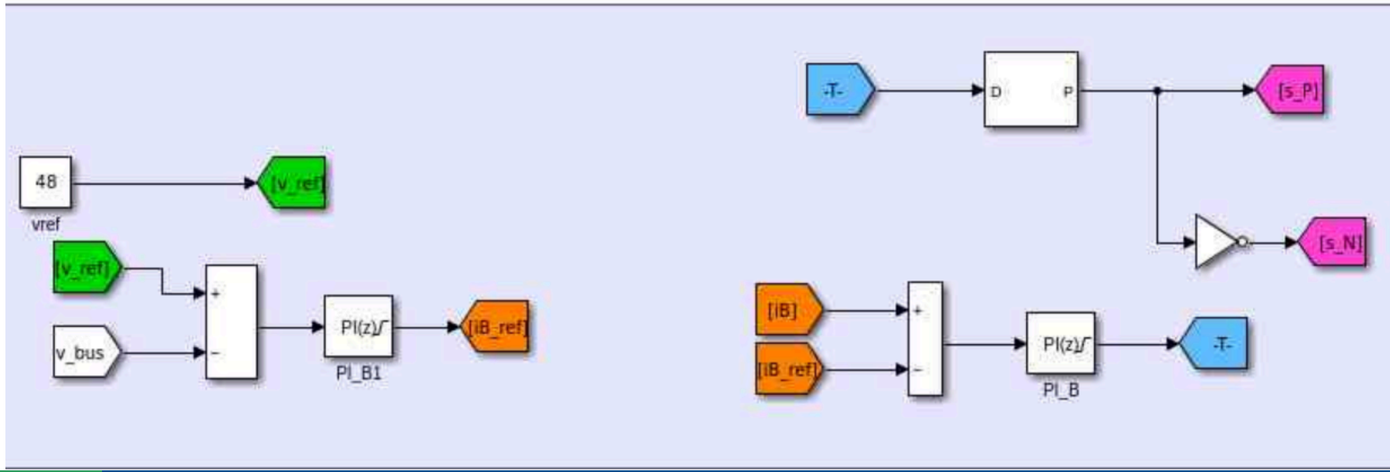
MPPT and Boost Converter Control



MPPT maximizes energy harvested from solar PV by adjusting the operating point.

Boost Converter Control regulates the expected bus voltage.

Bi-Directional DC-DC converter



Controls the charging and discharging of the battery based on surplus or low generation

MPPT Algorithm

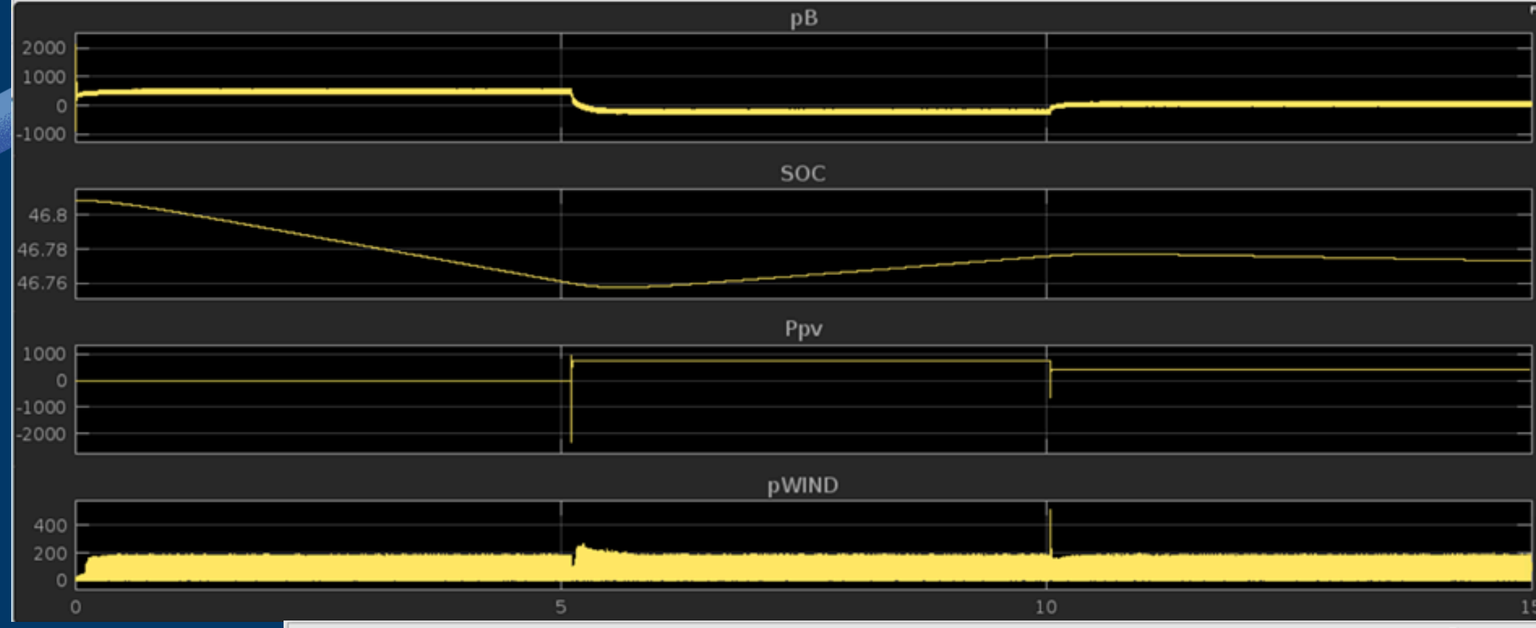
```
duty_init = 0.05;
duty_min = 0;
duty_max = 0.75;

persistant Vold Pold duty_old;

if isempty(Vold)
   Vold=0;
   Pold=0;
   duty_old=duty_init;
end

P= V*I;
dV= V - Vold;
dP= P - Pold;
duty = duty_old;
deltaD=deltaD_in;
```

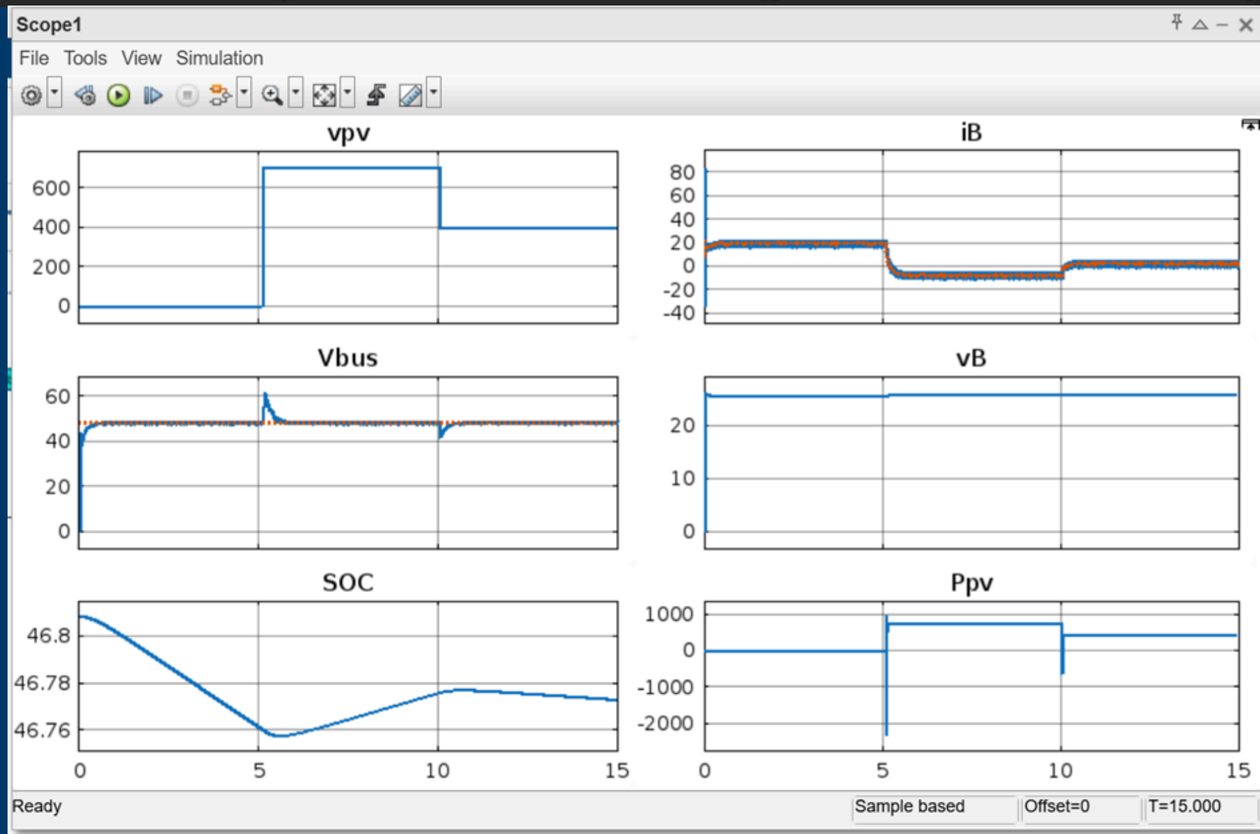
```
if abs(dP) > 0;
   if dP < 0
      if dV < 0
         duty = duty_old - deltaD;
      else
         duty = duty_old + deltaD;
      end
   else
      if dV < 0
         duty = duty_old + deltaD;
      else
         duty = duty_old - deltaD;
      end
   end

end
if duty >= duty_max
   duty=duty_max;
elseif duty < duty_min
   duty=duty_min;
end
```

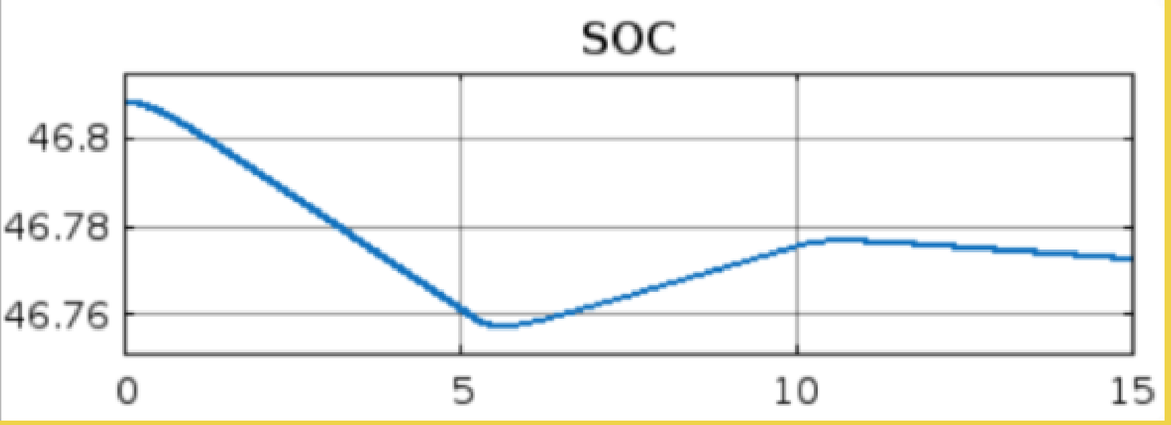
This code continuously adjusts the duty cycle to find and maintain the solar panel's maximum power point. It works by making small adjustments (`deltaD_in`) and observing how these changes affect power output. The logic ensures that the system moves in the direction of increasing power while staying within safe limits for the duty cycle.

Results

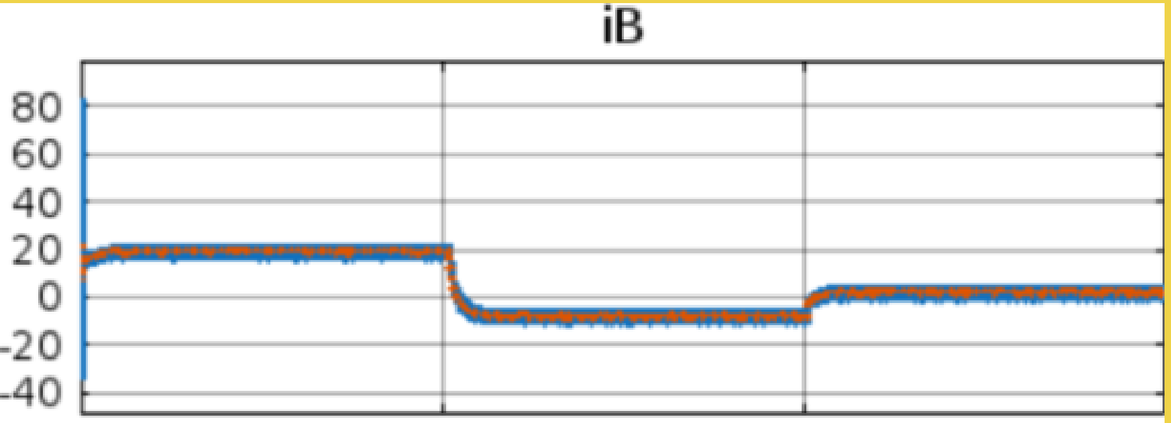
Observed results under changing environmental conditions such as Changing irradiance

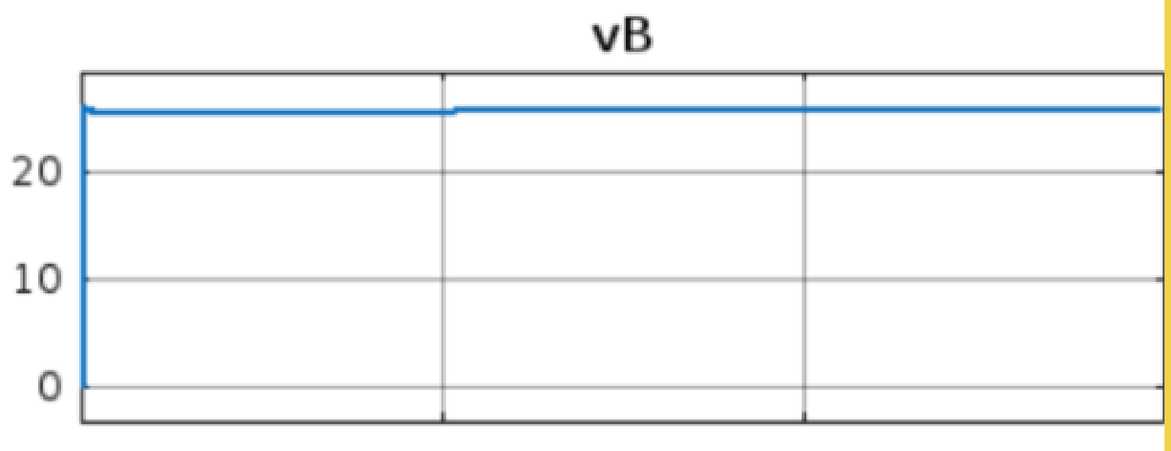






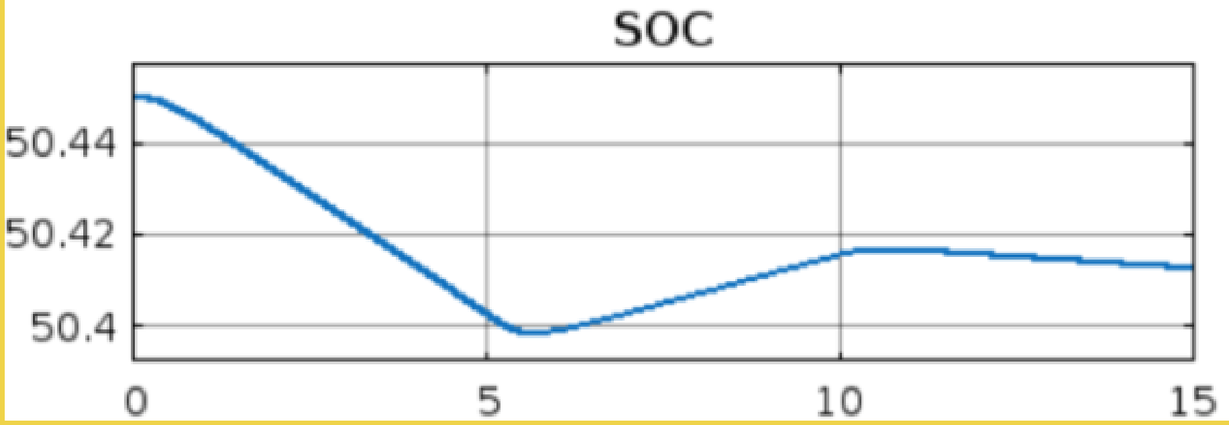
Lithium Ion



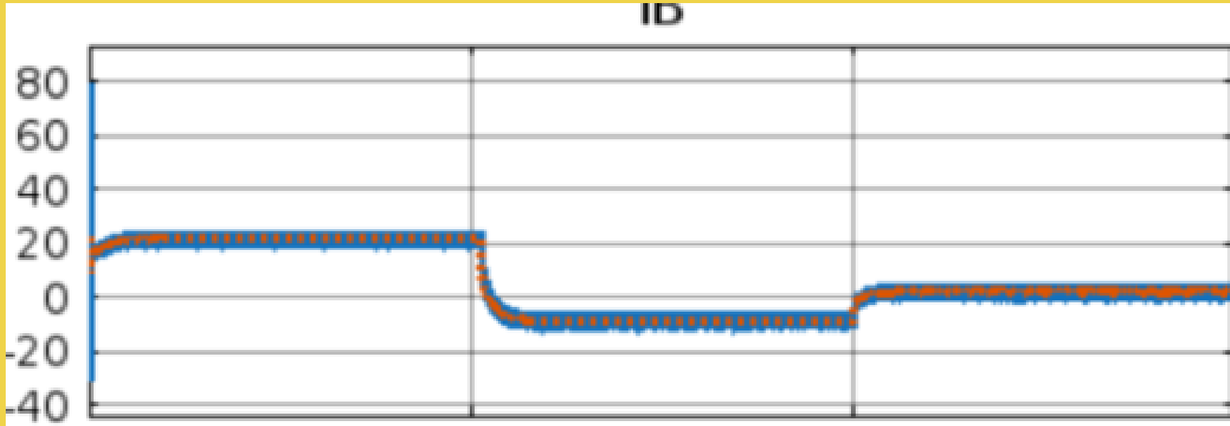


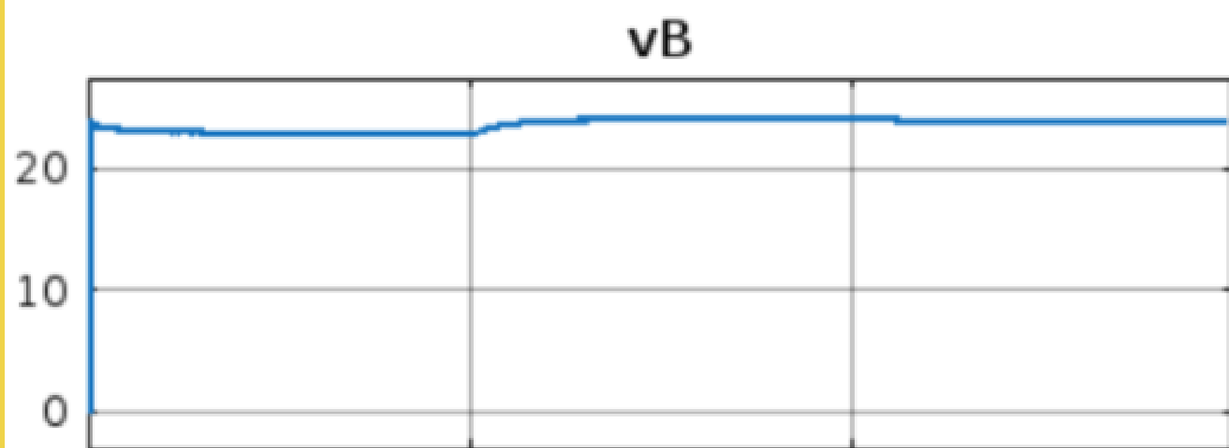
high efficiency , good response ,long life, expensive

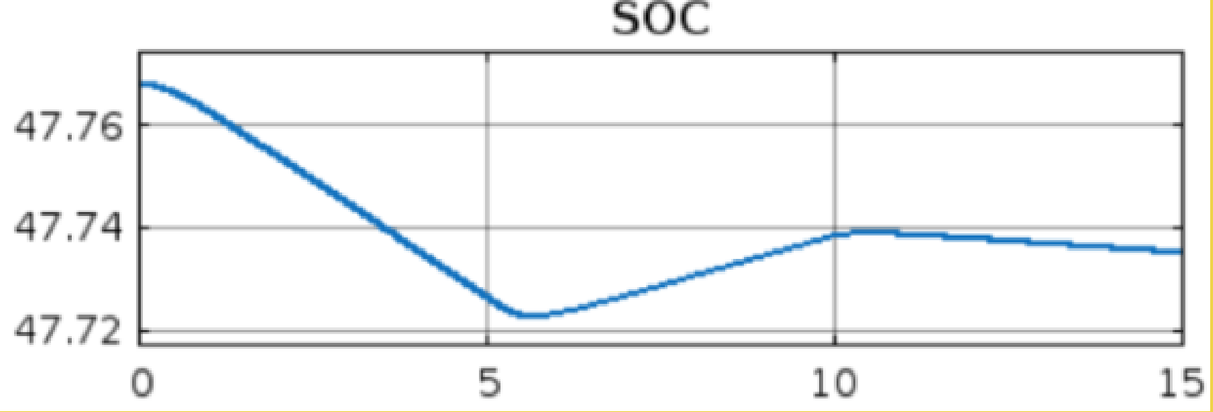
slow response, shorter life cycle, cost effective



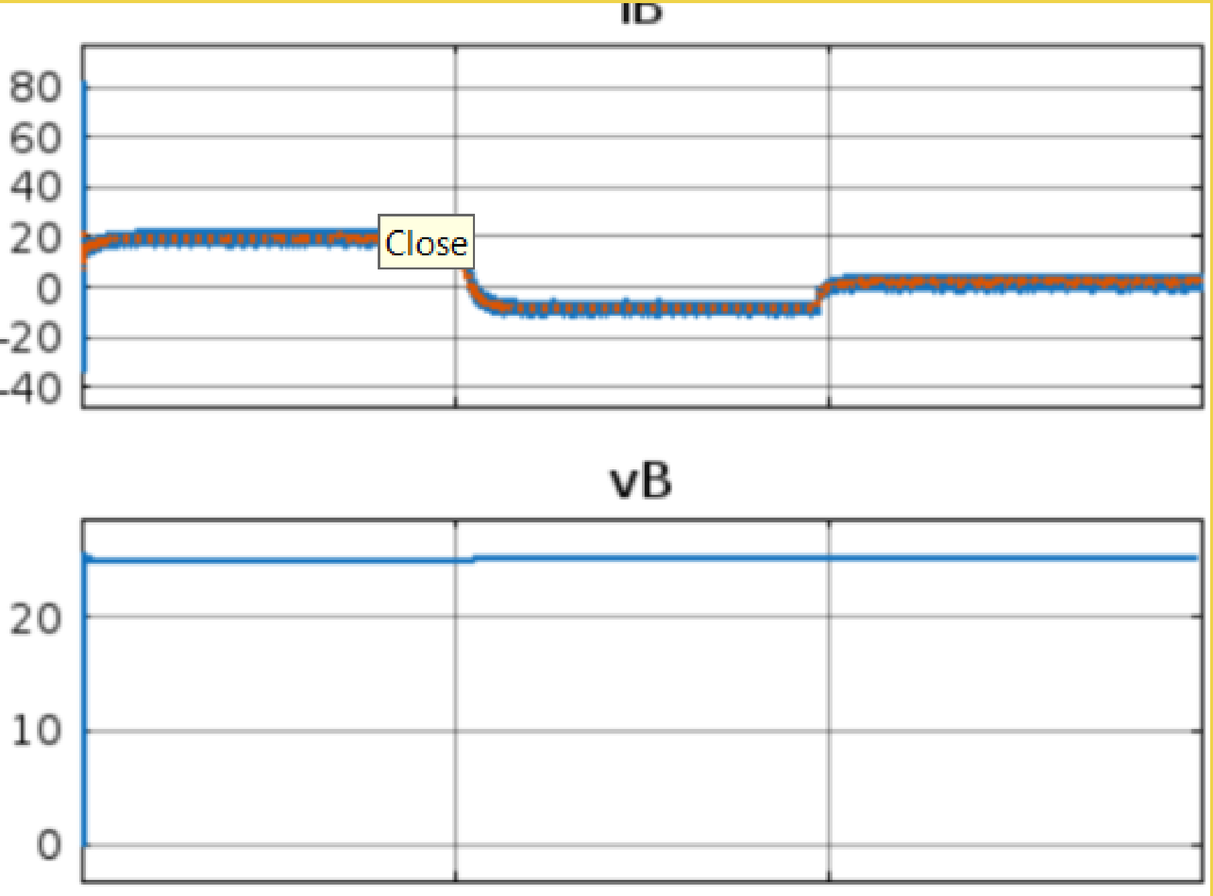
Lead Acid





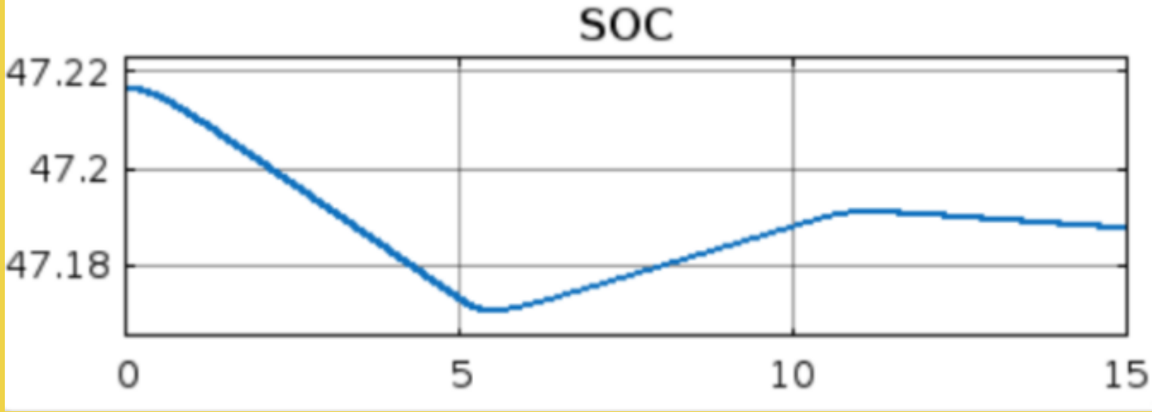


Nickel Cadmium

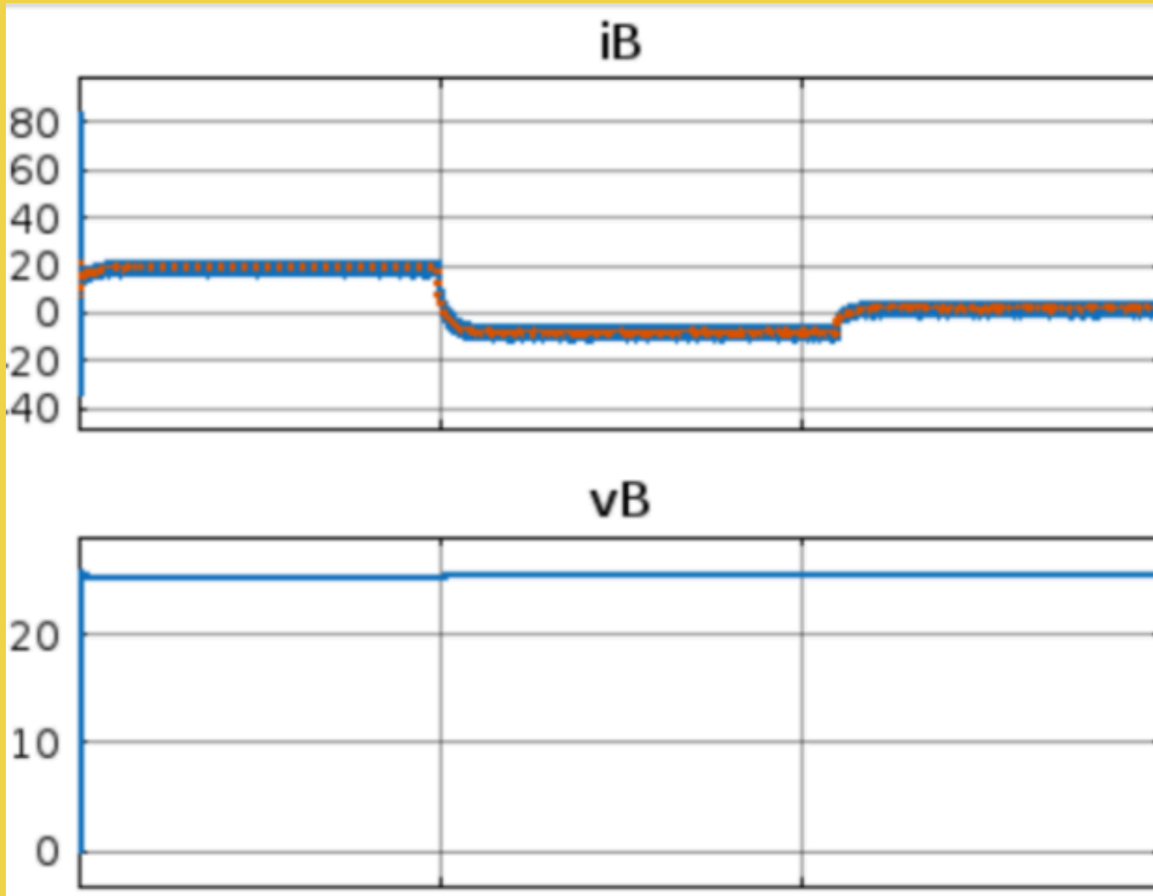


durable, harsh environment proof, capacity reduces over time

balance between cost and performance, poor response rate



Nickel Metal Hydride



Future Work

Further research and improvements in controller algorithms and energy management systems could enhance performance, minimize power fluctuations, and increase the overall efficiency of such systems

Conclusion

- The hybrid wind-solar-battery system is effective in providing stable power to DC loads.
- The system optimizes energy generation, storage, and consumption, ensuring high efficiency.
- This system can be scaled for residential and industrial applications, contributing to grn energy goals.