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Vehicle-to-Load (V2L) Simulation Using MATLAB

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Abstract - Vehicle-to-load (V2L) is an emerging technology in battery electric vehicles (BEVs) that allows the stored energy in the vehicle battery to power external electrical loads such as household appliances, power tools, and consumer electronics. A significant portion of a BEV battery remains unused during normal daily travel, making the battery an underutilized energy resource. This paper presents a MATLAB-based simulation of a V2L system and discusses its operation, converter requirements, inverter topologies, and pulse width modulation techniques used for power conversion. The study highlights how V2L can support emergency backup power, off-grid applications, and distributed generation concepts while improving the utilization of electric vehicle battery storage. The simulation demonstrates the feasibility of supplying external loads from a vehicle battery through appropriate DC-DC and DC-AC conversion stages.

Index Terms - battery electric vehicle, distributed generation, MATLAB simulation, pulse width modulation, vehicle-to-load.

I. Introduction

Vehicle-to-load (V2L) is a feature that enables an electric vehicle to provide regular AC power to appliances or loads such as lights, laptops, televisions, and refrigerators. Unlike vehicle-to-grid technology, V2L relies on an integrated inverter within the vehicle to supply power through one or more AC outlets.

V2L can be used for emergency backup power, charging other electric vehicles, camping applications, and off-grid power support. Since electric vehicles remain parked for a large percentage of the time, the battery can act as a distributed energy storage resource and help reduce dependence on conventional generation during peak demand periods.

II. Electric Vehicles

An electric vehicle (EV) uses one or more electric motors for propulsion and may be powered by batteries, fuel cells, or external electrical sources. The rapid growth of EV adoption has been supported by government incentives, environmental concerns, and advances in battery technology.

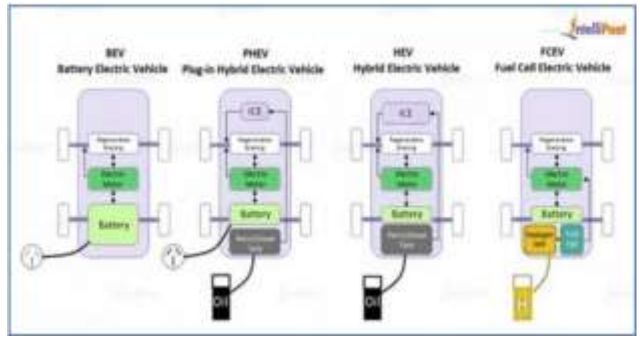

FIGURE 1. TYPES OF ELECTRIC VEHICLES.

A. Battery Electric Vehicle

A battery electric vehicle (BEV) uses rechargeable battery packs as its sole source of propulsion energy. BEVs use electric motors and motor controllers instead of internal combustion engines and derive all operating power from their batteries.

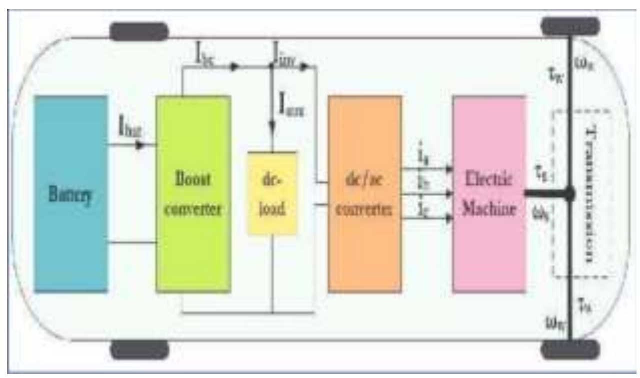

FIGURE 2. BLOCK DIAGRAM OF A BATTERY ELECTRIC VEHICLE.

B. Hybrid, Plug-In Hybrid, and Fuel Cell EVs

Hybrid electric vehicles combine an internal combustion engine with an electric propulsion system. Plug-in hybrid electric vehicles can recharge their batteries from the power grid, while fuel cell electric vehicles generate electricity using hydrogen fuel cells. Each topology offers different trade-offs in range, efficiency, infrastructure requirements, and emissions.

III. Power Converters for V2L

A V2L system requires efficient power conversion stages to deliver usable AC power from the vehicle battery.

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The primary converter categories are DC-DC converters and DC-AC converters (inverters).

A. Buck Converter

A buck converter is a DC-DC converter that steps down the input voltage while increasing the current available to the load. It is widely used for regulated low-voltage supplies and battery-powered systems.

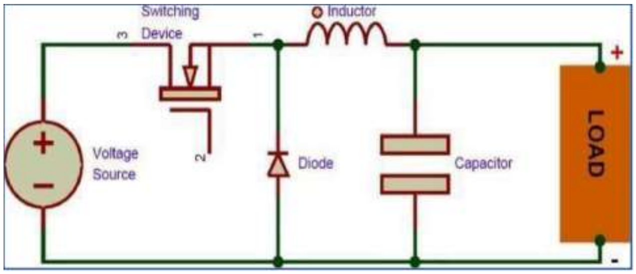

FIGURE 3. CIRCUIT DIAGRAM OF A BUCK CONVERTER.

B. Boost Converter

A boost converter increases the input voltage to a higher output voltage. It is commonly used in electric vehicles, renewable energy systems, and portable electronic devices where voltage amplification is required.

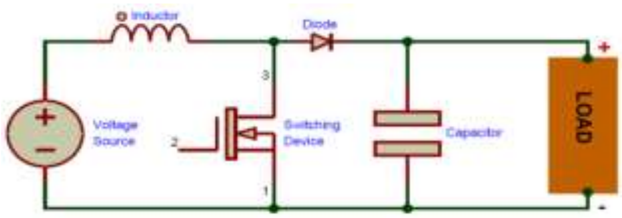

FIGURE 4. CIRCUIT DIAGRAM OF A BOOST CONVERTER.

C. Buck-Boost Converter

A buck-boost converter can either increase or decrease the input voltage depending on the operating duty cycle. This flexibility makes it suitable for applications where the battery voltage varies over a wide range.

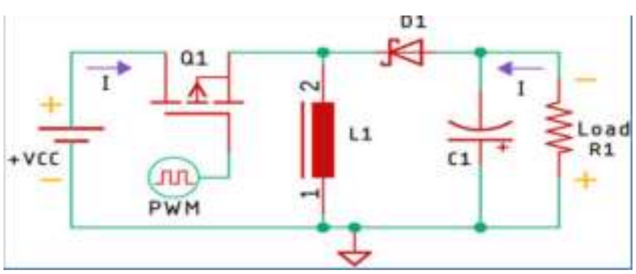

FIGURE 5. CIRCUIT DIAGRAM OF A BUCK-BOOST CONVERTER.

IV. INVERTER FOR V2L OPERATION

The DC energy stored in the vehicle battery must be converted into AC power before supplying household or portable loads. A voltage source inverter is commonly used because it provides a controllable AC output from a DC source.

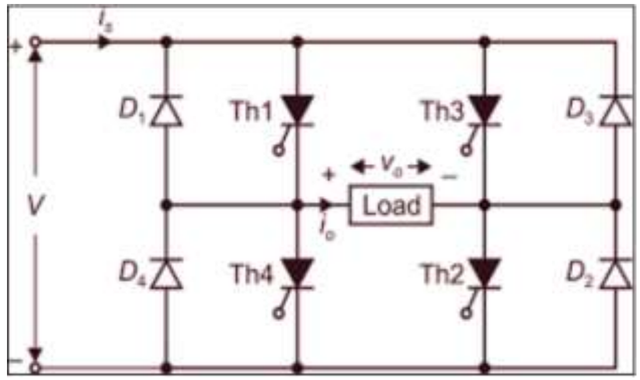

FIGURE 6. CIRCUIT DIAGRAM OF A DC-AC INVERTER.

Inverters may be classified as square-wave, modified sine-wave, or pure sine-wave inverters. Pure sine-wave inverters provide the highest power quality and are suitable for sensitive electronic equipment, although they are generally more expensive and slightly less efficient than simpler inverter topologies.

V. PULSE WIDTH MODULATION

Pulse width modulation (PWM) is used to control inverter switching and regulate the power delivered to the load. By varying the duty cycle of switching pulses, the average output voltage can be adjusted efficiently with minimal power loss.

Duty Cycle = T_on / (T_on + T_off). (1)

PWM provides fast response, high efficiency, and precise voltage control. However, higher switching frequencies can increase switching losses and electromagnetic interference.

A. Sinusoidal PWM

Sinusoidal pulse width modulation generates switching pulses by comparing a sinusoidal reference waveform with a high-frequency triangular carrier waveform. This technique significantly reduces harmonic distortion and produces an output waveform that more closely resembles a sinusoidal AC supply.

VI. MATLAB SIMULATION

The V2L system was modeled and simulated in MATLAB/Simulink. The simulation includes the battery source, DC-DC conversion stage, inverter stage, PWM control, and external AC load. The model demonstrates that the vehicle battery can successfully supply external loads through the converter and inverter stages while maintaining controlled output characteristics.

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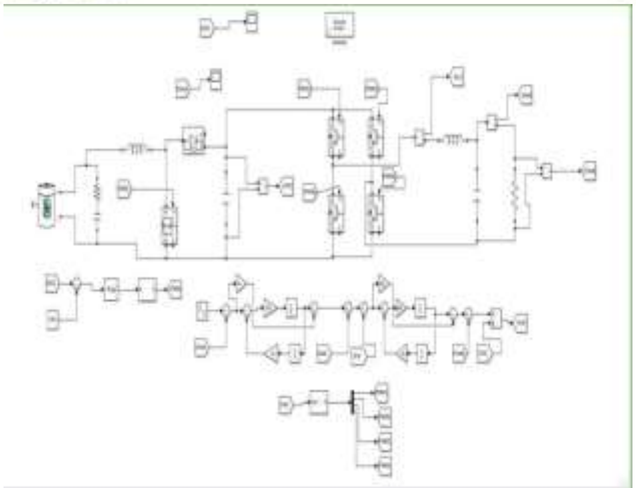
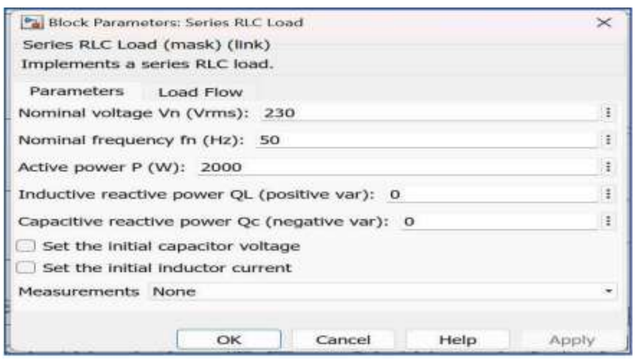


FIGURE 7. SIMULINK DIAGRAM

VII. RESULT

CASE 1: When the load is R Load with P = 2000W and Q = 0Var



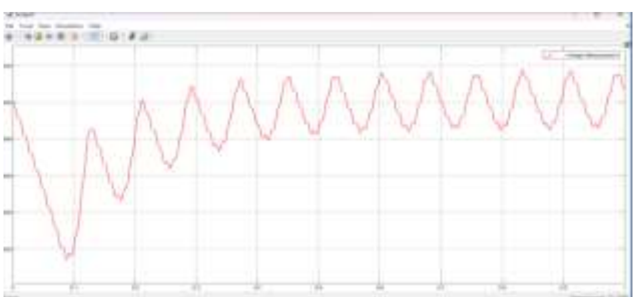


FIGURE 8. WAVEFORM OF GENERATED DC VOLTAGE(V_{DC})

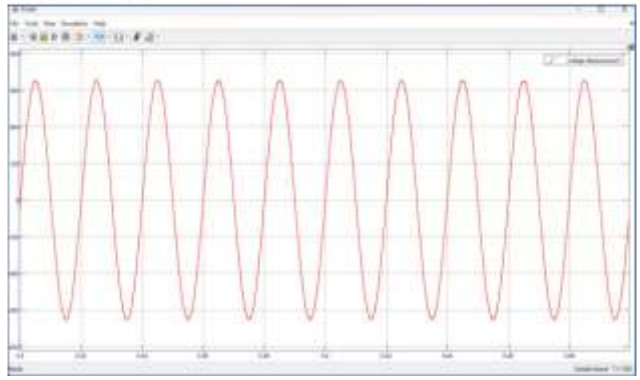
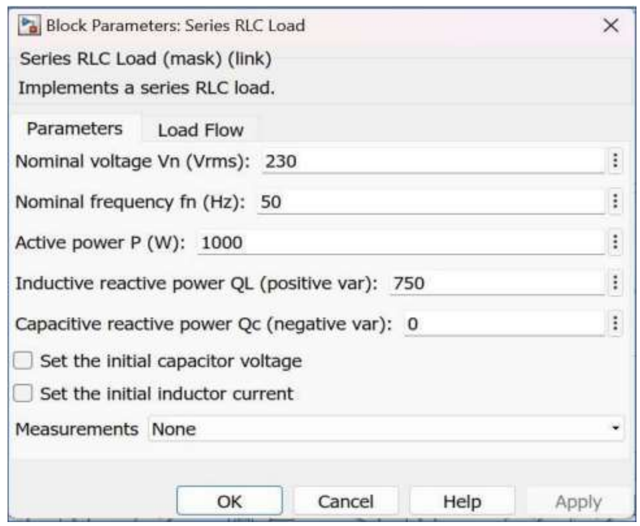


FIGURE 9. WAVEFORM OF VOLTAGE ACROSS LOAD (V_{LOAD})

CASE 2: When the load is RL (lagging pf load) with P = 1000W and Q = 750Var



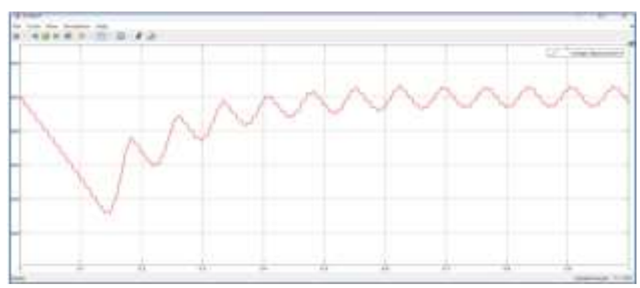


FIGURE 10. WAVEFORM OF GENERATED DC VOLTAGE (V_{DC})

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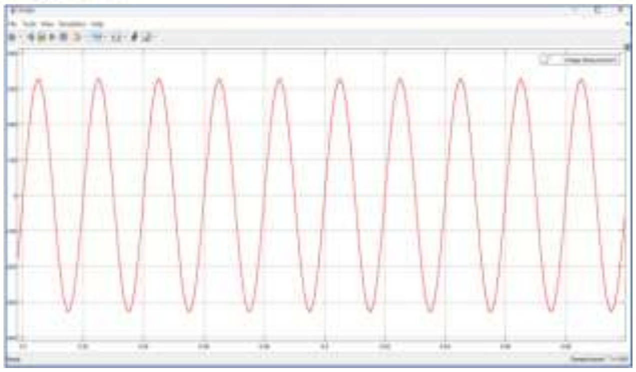

FIGURE 11. WAVEFORM OF VOLTAGE ACROSS LOAD (V_{LOAD})

VIII. Conclusion

This paper presents a condensed version of the project report on Vehicle-to-Load (V2L) simulation using MATLAB while preserving the original technical content. V2L technology enables electric vehicle batteries to act as distributed energy resources for supplying external loads, emergency backup power, and off-grid applications. The study highlights the role of DC-DC converters, inverters, and PWM techniques in achieving efficient power conversion. The MATLAB simulation demonstrates the feasibility of delivering controlled AC power from a vehicle battery, supporting the practical implementation of V2L systems.

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