HYBRID ELECTRIC VEHICLES (HEVs)

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INTRODUCTION

A Hybrid Electric Vehicle (HEV) is a vehicle that combines an internal combustion engine (ICE) with an electric motor, utilising energy stored in a battery to improve fuel efficiency and reduce emissions. HEVs can recapture energy through regenerative braking and offer improved fuel economy over conventional vehicles.

Key Objectives of HEVs:

- Reduction in fuel consumption and CO_2 emissions.
- Reduction in exhaust emissions for environmental benefits.
- Increased torque and power through electric assistance.

Key Components of HEVs:

- Internal Combustion Engine (ICE) – Uses alternative or conventional fuel.
- Electric Motor/Generator – Assists ICE and enables regenerative braking.
- Battery Pack – Stores electrical energy (Nickel-Metal Hydride (NiMH) or Lithium-ion (Li-ion), typically operating at 200-400V).
- Power Electronics – Manages power flow between the battery and electric motor.
- Transmission System – Transfers power to the wheels.

BENEFITS OF HEVs

- Improved fuel efficiency and lower emissions.
- Reduction in greenhouse gas emissions.
- Lower dependency on fossil fuels.
- Enhanced performance due to instant electric torque.
- Reduced brake wear due to regenerative braking.
- Extended driving range compared to Battery Electric Vehicles (BEVs).
- Self-charging (except PHEVs) without reliance on external charging stations.

TYPES OF HYBRID ELECTRIC VEHICLES (HEVs)

Parallel Hybrid Electric Vehicles

- Both ICE and electric motor drive the wheels.
- Electric motor assists during acceleration.
- Example: Honda Accord Hybrid, Toyota Camry Hybrid.

Series Hybrid Electric Vehicles

- Electric motor drives the wheels, ICE acts as a generator to charge the battery.
- Example: BMW i3 REx, Chevrolet Volt.

Series-Parallel Hybrid Electric Vehicles

- Can run on electric motor, ICE, or both.
- Intelligent power management optimises fuel economy.
- Example: Toyota Prius Hybrid Synergy Drive.

HEVs - PARTS AND CONTROL SYSTEMS

Main Components in HEVs

- Battery Pack – Stores and supplies energy to the electric motor.
- Electric Drive Motor – Converts electrical energy into motion.
- Internal Combustion Engine – Provides primary or backup propulsion.
- Power Control Unit (PCU) – Manages power between battery, motor, and engine.
- Transmission System – Transfers power from motor/engine to wheels.
- Regenerative Braking System – Captures and reuses kinetic energy.

Hybrid Control Systems

- Energy Management System (EMS) – Optimises fuel and electric power usage.
- Battery Management System (BMS) – Monitors State of Charge (SOC), State of Health (SOH), and cooling systems.
- Motor Control Unit (MCU) – Regulates torque delivery.
- Power Electronics Controller – Ensures seamless power distribution.

ENERGY FLOW IN HEVs AND PHEVs

Energy Flow in HEVs

- Idle Mode: ICE shuts off, electric motor remains inactive.
- Acceleration Mode: Electric motor assists ICE for increased power.
- Cruising Mode: ICE provides most power, electric motor assists when needed.
- Braking Mode: Regenerative braking captures energy and recharges the battery.
- Charging Mode: Battery charges during braking and ICE operation.

Energy Flow in Plug-in Hybrid Electric Vehicles (PHEVs)

- Grid Charging: PHEVs can be charged using external power sources.
- Electric-Only Mode: Runs entirely on battery power for a certain range.
- Hybrid Mode: ICE engages when battery is low or additional power is needed.

HEVs VS. PHEVs - SUITABILITY FOR INDIA

Comparative Study of HEVs & PHEVs in India

Feature	HEV	PHEV
Charging Requirement	No	Yes (Plug-in)
Fuel Consumption	Lower than ICE	Lower with grid charging
EV Range	Limited	30-80 km (Battery-Only Mode)
Cost	Moderate	Higher due to battery size
Suitability in India	High (No charging infra required)	Moderate (Charging infra needed)

Conclusion:

- HEVs are more suitable for India due to lack of widespread EV charging infrastructure.
- PHEVs could be an option if charging stations expand.
- Government incentives could drive PHEV adoption in the future.

FUTURE TRENDS IN HYBRID VEHICLES

Emerging Innovations:

- 48V Mild Hybrid Systems for improved efficiency.
- Wireless Charging for PHEVs.

- AI-Based Predictive BMS for Optimal Energy Distribution.
- Solid-State Batteries for enhanced energy density.
- Next-Generation Hybrid Powertrains with Variable Compression Ratio Engines.

Best Practices for Hybrid EV Development:

- Use AI for Smart Energy Management – Optimise power transitions.
- Enhance Regenerative Braking Algorithms – Maximise efficiency.
- Adopt Digital Twin & Cloud-Based BMS – Real-time analytics & updates.
- Ensure Compliance with Global Regulations – ISO 26262, SAE J2929.
- Improve Thermal Management Systems – Prevent overheating.