


Improved Fuel Economy of Through-the-Road Hybrid Electric Vehicle with Fuzzy Logic-Based Energy Management Strategy

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Abstract Hybrid electric vehicle (HEV) provides drivers with uncompromised drivability while significantly reducing hazardous emissions. This is achieved through optimal power flow solution via energy management strategy (EMS) which efficiently handles energy distribution from the different energy sources of a HEV. In this paper, a through-the-road (TtR) HEV configuration with fuzzy logic-based EMS is proposed. Fuzzy logic is applied in the main control block of the vehicle with a pair of membership functions assisting the power flow controller to select the appropriate power distribution by the hybrid drivetrain based on available resources in real time. The EMS operates in hybrid mode blended control strategy to achieve minimum fuel consumption for the desired trip by prioritising the electrical drivetrain over the internal combustion engine (ICE) for power distribution to the wheels. A Simulink model was constructed in MATLAB[®] to represent the TtR HEV equipped with in-wheel motors (IWM) in the rear wheels. A fuzzy logic-based EMS controller has been synthesised. The power flow in the TtR HEV is decided based on current vehicle speed and the global discharge rate (GDR) value derived from the current state-of-charge (SOC) of the battery and remaining trip distance. The proposed controller performs well on standard drive cycles and offers up to 62% improvement in fuel consumption compared to the reference model which uses rule-based EMS. Comparisons against other published

models are equally encouraging, especially on high average speed drive cycles with up to 19.8% improvements in fuel consumption.

Keywords Hybrid electric vehicle · Energy management strategy · Through-the-road HEV · Fuzzy logic-based EMS · Hybrid mode blended control strategy

List of Symbols

g	Gravitational acceleration = 9.81 m/s ²
β	Road incline angle
m	Vehicle total mass
V_x	Longitudinal vehicle velocity
V_W	Wind speed (+ for headwind, – for tailwind)
n	Number of wheels on each axle
F_{xf}, F_{xr}	Longitudinal forces on front and rear wheels at ground contact points
A_F	Effective frontal vehicle cross-sectional area
C_d	Aerodynamic drag coefficient
ρ	Mass density of air = 1.18 kg/m ³
F_{zf}, F_{zr}	Normal forces acting on front and rear wheels at ground contact points
h	Height of vehicle's centre of gravity above the ground
F_d	Aerodynamic drag force
a, b	Distance of front and rear axles, respectively, from centre of gravity
V_{batt}	Battery voltage
E_0	Battery constant voltage
K	Polarisation constant
Q	Battery capacity
$it = \int idt$	Actual battery charge
A	Exponential zone amplitude
B	Exponential zone time constant inverse

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