III. ELECTRIC-PROPULSION SYSTEMS FOR HEVS

A. DC Motors

Inexpensive and controllable direct current (DC) motors have been prevalent as a source of power for electric vehicles in recent history, although they have some benefits, there are also some drawbacks which make their use in Hers difficult. High speed coupled with a low torque to weight ratio leads to inefficient performance of DC motors, and the gradual degradation of the brushes in this machine necessitates frequent maintenance. In addition, high EMI emissions resulting from using solid-state power electronics to manage DC motor velocity can lead to issues with other electronic components installed within the vehicle.

B. Induction Motors (IMs)

The hardiness and dependability of IMS paired with their low cost makes them an attractive option for industrial applications, and the use of IMs in Hers presents several advantages including efficient operation and minimal EMI emission levels while maintaining a strong degree of controllability. Although there are advantages to using them there are also disadvantages including the loss of energy due to rotor speed, so to regulate speed and torque levels sufficiently an inverter is a must-have addition that results in increased costs for these systems.

C Permanent Magnet Synchronous Motors (PMSMs)

PMSMs have the necessary features such as high-power density and efficiency along with good controllability making them suitable for use in HEV propulsion systems, and with the help of low rotor losses at high speeds, they can improve their productivity. While PMSMs offer significant benefits there are inherent limitations such as a high cost attributed to the usage of rare earth metals for magnets and an absolute necessity for intricate control algorithms that retain magnetic field alignment.

D. Switched Reluctance Motors (SRMs)

Good controllability along with other advantages such as low cost and high efficiency make SRMs an ideal option for HEV applications while the simplicity and robustness of their design brings down the cost of upkeep. Still though SRMs come with certain constraints including high torque ripple and acoustic noise that are hard to manage.

The cage IM motor was found to be the best option for electric-propulsion systems in parallel hybrids due to its efficiency, cost-effectiveness, and reliability, as well as its controllability and low EMI emissions. However, choosing the right electric-propulsion system for an HEV requires considering factors such as driver expectations, vehicle constraints, and energy sources to ensure the optimal system is selected.

The comparative study analyzed the requirements and configuration of a parallel hybrid electric vehicle (HEV), where the ICE and electric motor work together to generate energy for wheel rotation, aided by the electric-assisted ICE to reduce emissions and fuel consumption. Only the ICE and electric motor are used as propulsion devices, with a smaller ICE and electric motor utilized until the battery is depleted. Effective sizing of the electrical motors achieves the optimal balance between fuel efficiency and on-road performance, such as speed and torque. Hybridization benefits HEVs in terms of improved fuel economy and dynamic performance until reaching a critical level of improvement beyond which expanding the electric-propulsion system's capacity yields little gain, supported by research findings.

When choosing an electric motor for HEV propulsion, high instant power and power density, high torque at low speeds, wide speed range variation, and fast torque delivery are crucial characteristics. These machines offer impressive efficiency levels and reliable performance, with torques aligning with speed ranges. The electric propulsion system must operate flawlessly even with faults present, and considering the market acceptance and availability of associated power converter technology is vital for cost-effectiveness.

Fig. 3 shows that electric motors used in EVs and HEVs have a continuous torque region until the rated speed and a continuous power region beyond it. The profile of active effort versus speed on the driven wheels is determined by examining the characteristics of both power source and transmission, maintaining a stable power output within its range of motion and subsequently decreasing in a hyperbolic fashion with increased vehicle velocity. The hybridization factor (HF) determines these traits.

Regarding synchronous motors, such as PM brushless and switched reluctance motors (SRMs), for HEV propulsion, PM brushless motors have limited field weakening capability, resulting in a short constant-power region, despite their advantages of high-power density, high efficiency, and efficient heat dissipation. Conduction angle control can extend the constant-power region, improving speed range and efficiency. PM hybrid motors reduce the air-gap field during high-speed constant-power operation with an extra field winding. PM brushless motors work best for wheel direct-drive motor applications, and SRMs are simple and rugged, operating in a fault-tolerant manner. Although SRMs offer easy control and outstanding torque-speed characteristics, drawbacks such as acoustic noise, torque ripple, excessive bus current ripples, and electromagnetic-interference noise generation must be addressed to make them a feasible option for transportation. Table 1 reviews electric propulsion recently adopted in the automotive industry.

This study focused on electric motors for hybrid cars using electricity and gas. The IM motor is effective for city driving, but PM brushless motors also work well. Efficient operation at different speeds is crucial for these motors. Some car manufacturers use both types of motors. A new flat and cost-effective IM motor has been developed, offering benefits such as smooth driving, lower costs, and the ability to operate at higher temperatures and speeds.