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Designing A Multi Level Inverter System for Propelling Parallel Hybrid Electric Vehicles

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Abstract-Design and development of a cascaded H-bridge multilevel inverter-based parallel hybrid electric car. To increase the overall economy and performance of the electric car, the suggested system combines the benefits of a parallel hybrid engine with a high-efficiency cascaded H-bridge multilevel inverter. The results of modelling and simulating the suggested system using MATLAB/Simulink demonstrate that it can reach a high level of performance while lowering energy use and emissions.

Keywords-CascadedMultilevel Inverter, Harmonic Distortion, MATLAB, semiconductor switches, THD.

Introduction

Energy saving and fuel economy are at the center of an ever-growing research effort on a global scale, as evidenced by the massively increasing electrified vehicles and their components being rolled out in the market. While innovating fossil fuels based thermal-propulsion technology for combustion engines has limited scope to meet pledges to cut carbon emissions and address the urgency of the climate crisis, hybrid electric propulsion is making disrupting changes to support the global transition into a carbon-neutral future. Arguably, the pioneering advances in efficiently combining thermal engine (for long-range travel), and electric motor drives (based on power electrics control) are influencing the next generation of electric-powered vehicles.

Multilevel multicellular converter (inverter) possesses many properties that make them highly interesting for hybrid electric vehicle (HEV) applications, e.g., negligible total harmonic distortions (THD) in the staircase waveform free of bulky filters, modular configuration with fault tolerance for battery packs (lithium-ion cells), and bidirectional current control for battery recharging during regenerative braking. A 15-level cascaded H-bridge (CHB) inverter model deployed in this work is depicted in Fig.2, with 7 identical H-bridge modules connected in series at each phase. Fuel economy of HEV is linked to the motor drives, more specifically, the control of the multilevel inverter, but its full action and impact on the hybrid. Propulsion is only just beginning to be understood. To this end, a sequence of models underpinning these are developed in this work and characterized by simulations using MATLAB Simulink. Firstly, a phase-shifted pulse-width modulation (PSPWM) for the 15-level CHB inverter is presented in section II, describing the control circuits, and reporting the simulated output analysis. Incorporating the inverter control, section III reports the motor drives modelling results of adjustable speed and regenerative braking. A parallel HEV model is built up with fuel economy balanced between the electric motor and the internal combustion engine. Conclusions are drawn in section. In Fig.2each block contains one H-bridge and all H-Bridges are connected in series with another H-bridge.

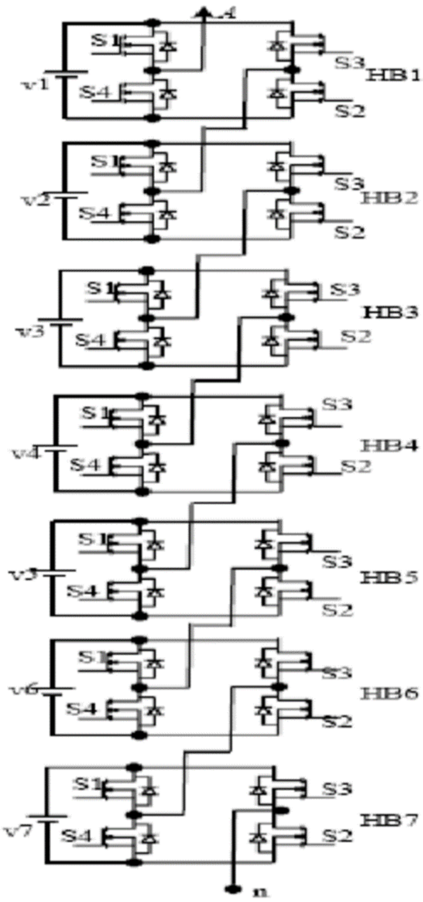

Fig.1 Symmetric cascaded H-bridge 15-level inverter model in this work

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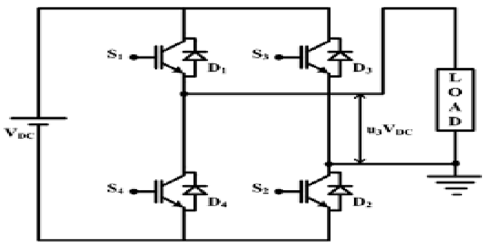
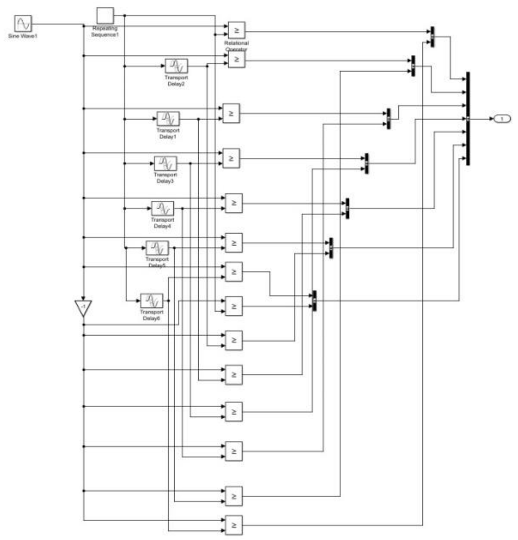


Fig.2 Cascaded H-bridge multi-level inverter.

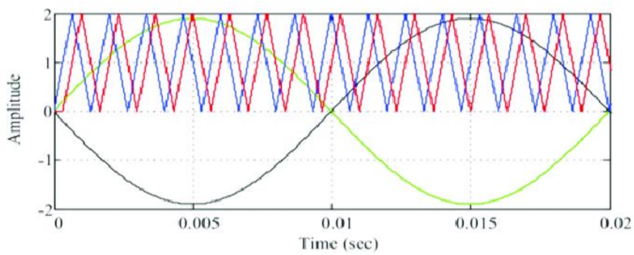
Modulation control for multi-level inverter

A.Control circuit for phase shifted PWM.

a phase-shifting PWM (PS-PWM) method that differs from the majority of existing CHB control methods that use phase dispositions PWM. In this PS-PWM, all carriers have the same height but are horizontally shifted by a specified angle, which is achieved using six time-delay blocks. Each carrier is progressively phase shifted by an angle of 180/7=25.714 degrees. To reduce costs and complexity, a reversed sinusoidal reference is introduced, allowing for the number of carriers to be halved. The circuit for generating the required triangular carrier signals is shown in Figure 3 (b). The time delay units used in the experimental setup and circuit implementation are tunable phase shifting prototypes with high figure-of-merits in terms of the ratio of phase tuning range to insertion loss.



(a)

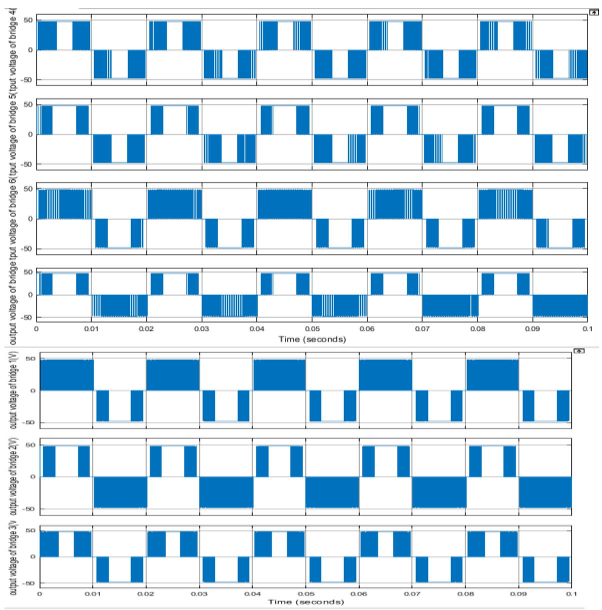


(b)

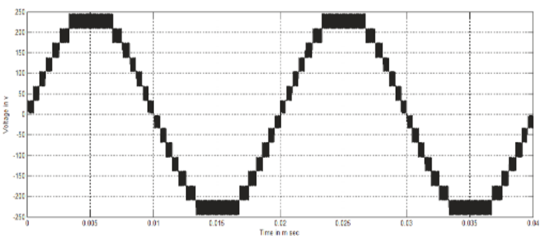
Fig.3 Modelling PS-PWM :(a) control unit design;(b) produced sinusoidal reference and shifted carrier.

B.Simulation results of output voltage and stator current.

In Fig. 4(a), the output voltages of bridges 1 to 7, arranged from top to bottom, are shown as controlled by the PS-PWM. These voltage steps are synthesized to generate 15-level phase-to-neutral voltages, as depicted in Fig. 4(b)&4(c). The Fast Fourier Transform (FFT) analysis of the stator current is presented in Fig. 5. The results show a nearly ideal sinusoidal waveform without requiring extra filtering, highlighting the advantages of using a multilevel inverter over traditional 2-level inverters. This demonstrates opportunities for multi-objective optimizations, such as using a novel windowed PWM technique. These findings suggest the potential for improving the performance and efficiency of power electronics systems.



(a)



(b)

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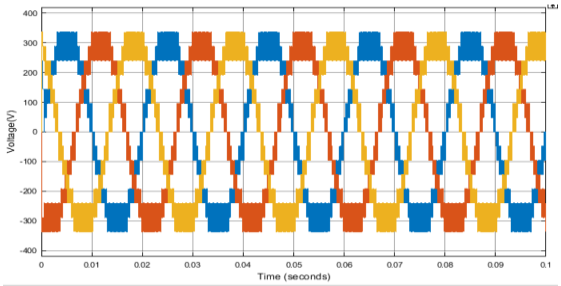


(c)

Fig.4Simulation results of (a) output voltages of bridge 1 to 7(phase A); (b) outputvoltages one phase;(c) 3-phase output voltage.

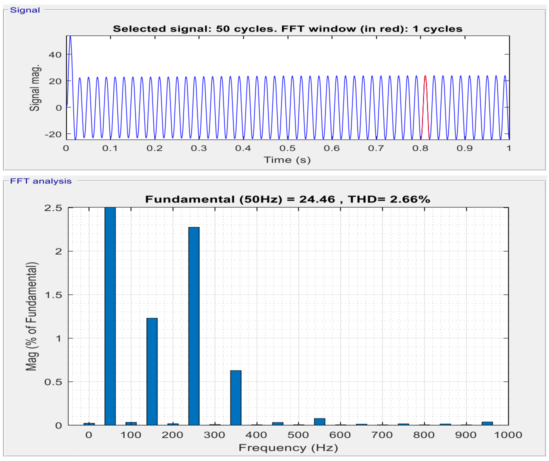
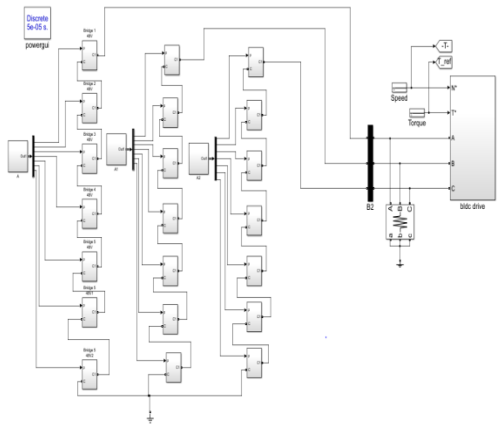


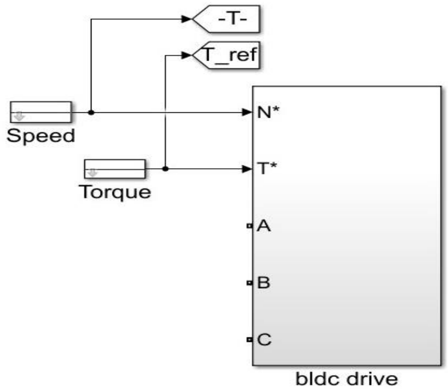
Fig.5 THD value

Simulation of motor drives

The modulation scenario developed for the 15-level inverter is applied to hybrid electric vehicle (HEV) drives to evaluate its performance. In this experiment, the reference values of the speed and torque of the BLDC motor are set to Nref=15000 RPM and Tref=5 N-m, respectively. The resulting torque, stator current and speed of the motor are shown in figure 7. This analysis provides insights into the ability of the 15-level inverter to control the motor under different operating conditions. These findings are crucial in the design and development of power electronics systems for HEVs, as they demonstrate the potential for improved performance and efficiency in these applications.



(a)



(b)

Fig.6 Simulation of motor drives: (a) simulation circuit with BLDC motor;(b) Reference speed and torque circuit

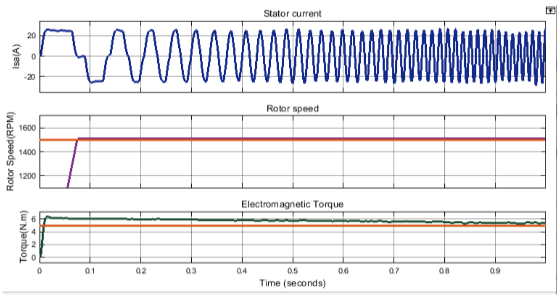


Fig.7 stator current, Torque&speed

Conclusion

A vehicle traction simulator of hybrid propulsion motor drives is presented based on phase-shifted pulse-width modulation of a cascaded H-bridge 15-level inverter with adjustable speed and regenerative braking functionalities. Energy recuperation and fuel economy are realized by the internal combustion engine operating at the sweet spot with the assistance of multilevel inverters to manipulate electric drives. The developed simulating model not only applies for ground vehicles, but also has implications in the ongoing

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electrification of airplanes and helicopters with turbine engines.

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