Multi-Source Inverter for Hybrid Electric Vehicles

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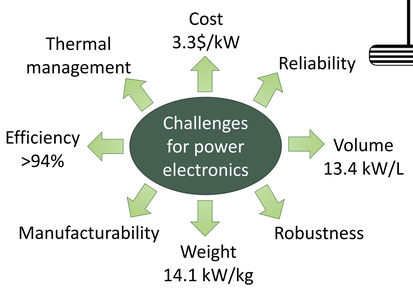
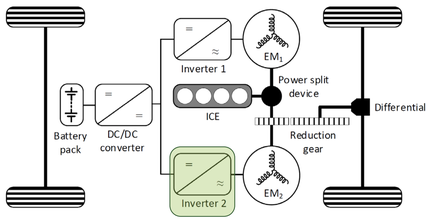
HYBRID ELECTRIC VEHICLE POWERTRAIN

Every component in an electrified powertrain is subjected to aggressive targets and intensive researches attempt to reach the goals defined by the U.S. Department of Energy for 2020.



Hybrid electrified powertrain in a power-split configuration.

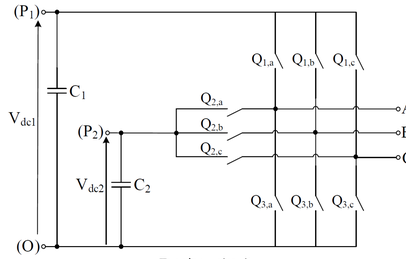


Research focus area:
Traction inverter

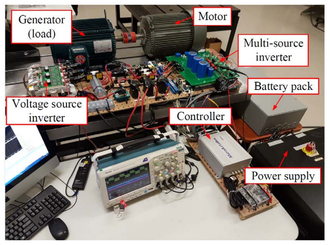
Innovative topologies could be a solution among the multiple opportunities to overcome the barriers for power electronics and design the next generation inverter.

MULTI-SOURCE INVERTER

The multi-source inverter is a power converter which aims to connect two DC sources, namely V_{dc1} and V_{dc2}, to the same AC output using a single stage of conversion.



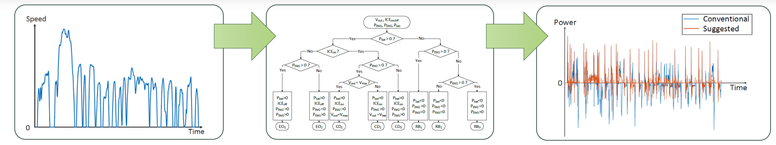
Topology circuit.



Experimental setup.

The uniqueness of the topology lies in the DC side connection that greatly differs from other inverters. Indeed, three switches in each phase leg connect two independent input DC sources to the same AC load. Due to this particular feature, both sources can provide power to the AC output with an adaptable voltage, depending on the operating modes.

POWERTRAIN COMPARISON

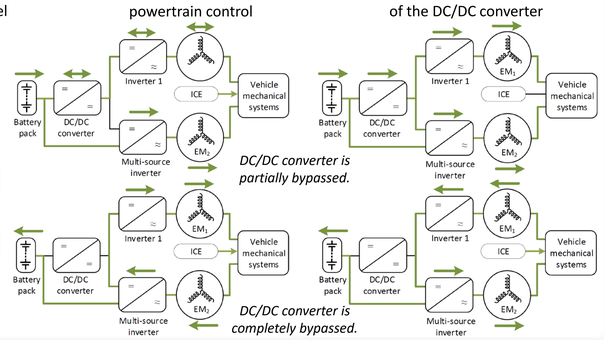


Several drive cycles are applied to the simulation model

Use of similar advanced powertrain control

Comparison of the power profile of the DC/DC converter

3 power profiles compared to the conventional powertrain
Identical
Partially reduced
Fully reduced



POWERTRAIN CONTROL

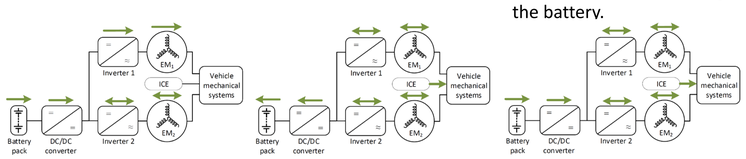
Control systems in modern electrified powertrains use elaborated control strategies to manage the power distribution between the electric machines (EMs), the engine (ICE) and the battery pack.

Three main modes

Electric-only
The battery is the only source of power to drive the wheels and the ICE is turned off.

Combined driving
The ICE is turned on to assist the battery and both provide power to the wheels.

Regenerative braking
The ICE drives the wheels and a portion of the engine power or the kinetic energy are transferred to charge the battery.



Electric-only mode. *Combined driving mode.* *Regenerative braking mode.*

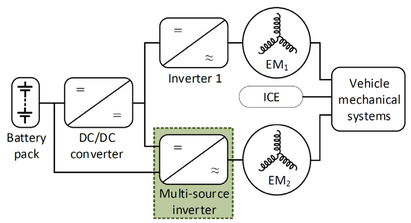
Both electric machines can operate as motor or generator and the speed and torque are controlled depending on the optimal operating point for the engine to ensure high efficiency.

OPERATING MODES

Regarding to the state of the switches, three different input voltages can be applied to the output line-to-line voltages, implying three distinct operating modes.

Operating modes	Switches used	Input DC voltage applied to the load	Characteristic
1	$Q_{2,abc}$ and $Q_{3,abc}$	V_{dc2}	Only the battery supplies the motor.
2	$Q_{1,abc}$ and $Q_{2,abc}$	$V_{dc1} - V_{dc2}$	The high DC-link voltage supplies the motor while charging the battery at the same time.
3	$Q_{1,abc}$ and $Q_{3,abc}$	V_{dc1}	Only the high DC-link supplies the motor. The battery is not used.

When the multi-source inverter is applied to hybrid electric powertrains, V_{dc1} represents the DC-link voltage shared with the other inverter while V_{dc2} is supplied by a battery pack.



Suggested powertrain with the multi-source inverter.

SUGGESTED POWERTRAIN BENEFITS

Similar advantages of supplying the load with a high variable voltage like in conventional powertrains

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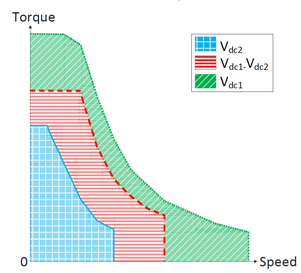
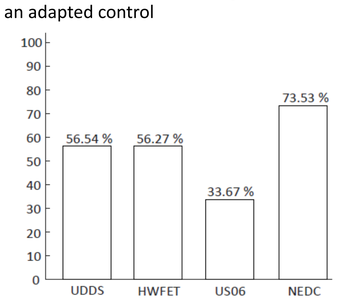
Opportunity to partially or entirely bypass the DC/DC converter under four driving conditions

- Extension of the constant torque characteristic
- Reduction of the current rating in the switches
- High efficiency areas of the inverters and the electric machines even at light load



Simplified torque-speed characteristic with the multi-source inverter.

- Significant average power reduction of the DC/DC converter
- Future potential power rating reduction with an adapted control



Average power reduction of the DC/DC converter with the suggested powertrain depending on the drive cycle (in %) .

We acknowledge the support of the Ontario Research Fund: Research Excellence Program.

We acknowledge the support of the Natural Sciences and Engineering Council of Canada (NSERC), which invests annually over $1 billion in people, discovery and innovation.