Improving On-Road Safety: Embedded Limp-Home Strategy for Electric Vehicles

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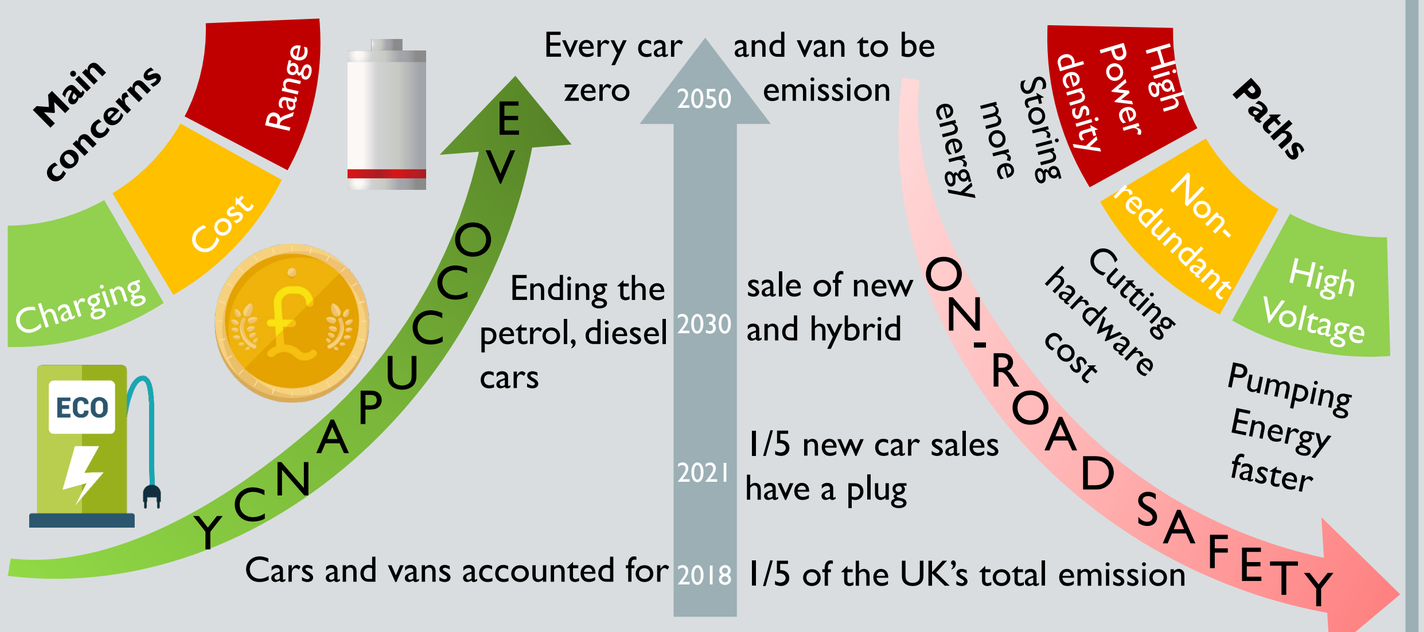
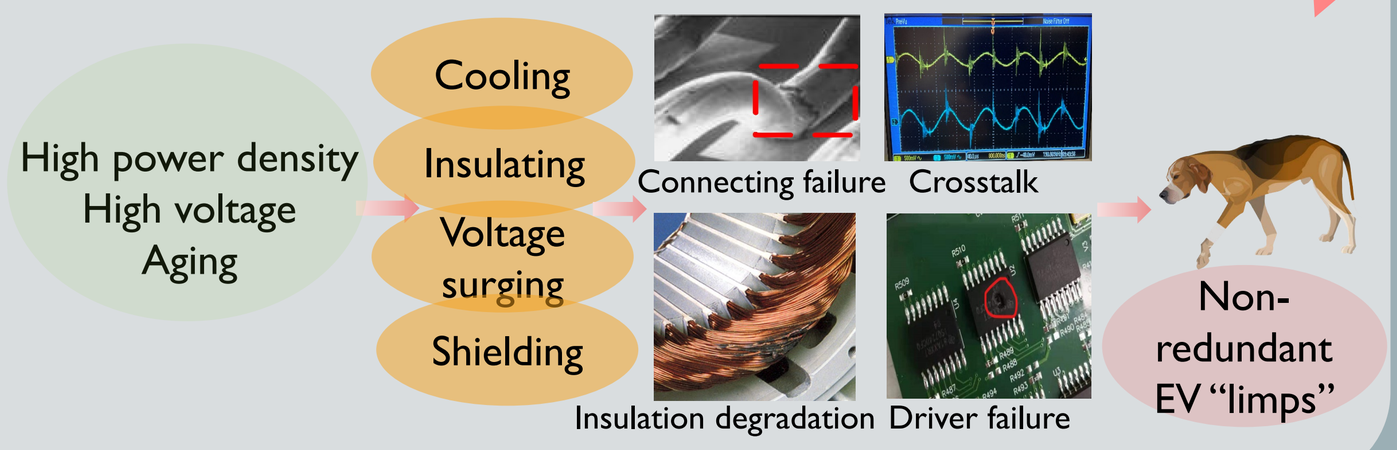
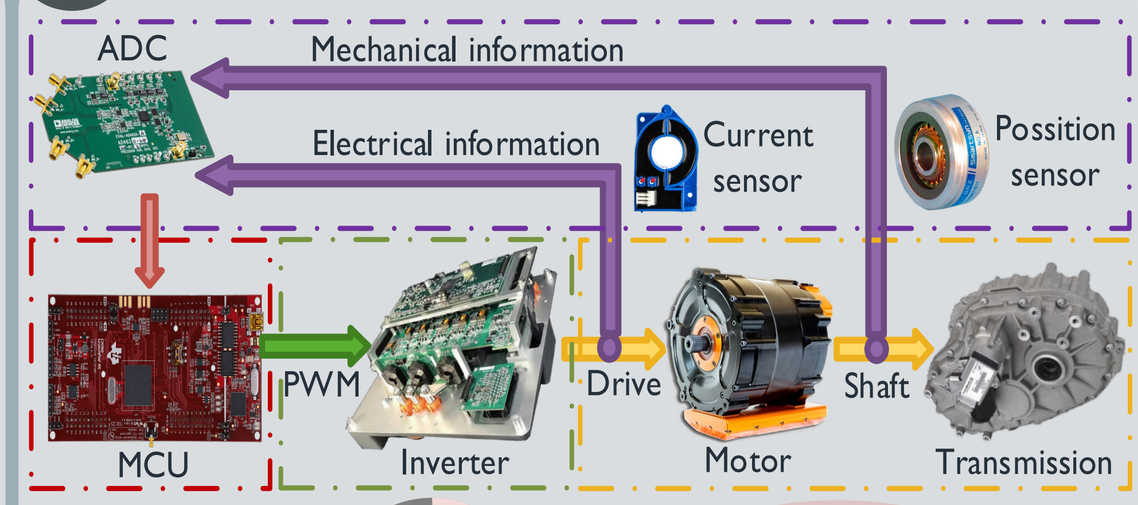
1 Challenges on EV Safety





2 Review on EV Powertrain



Open-circuit is the ultimate phenomenon of inverter failures

38% of failures in motor drives

How to update the safety of existing EVs?

- Multi-phase System
- Paralleled Inverter
- 4-leg Inverter
- Split DC Capacitor

- Unavailable to on-road EVs, unless substituting their powertrains.
- Only employed in a few high-end EVs due to the cost

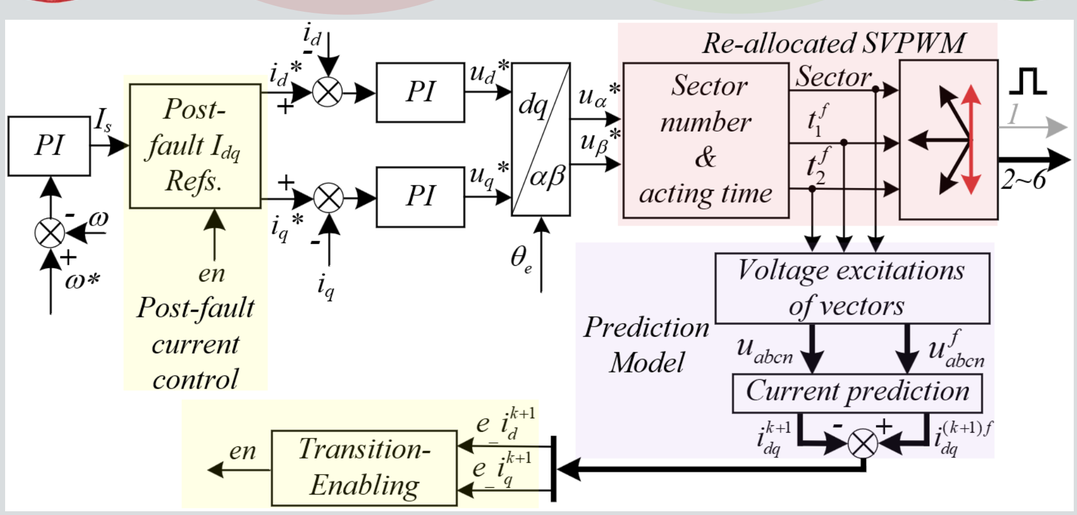
Mercedes-Benz EQS employs 6-ph motor fed by 6-ph inverter.

Price from 100k GBP

3 Proposed Limp-Home Strategy

With hard-ware auxiliaries?

Without hard-ware auxiliaries?



A novel current prediction model for detection

- Track post-fault responses to compare with real-time feedback, so as to detect the fault and trigger the tolerant strategy

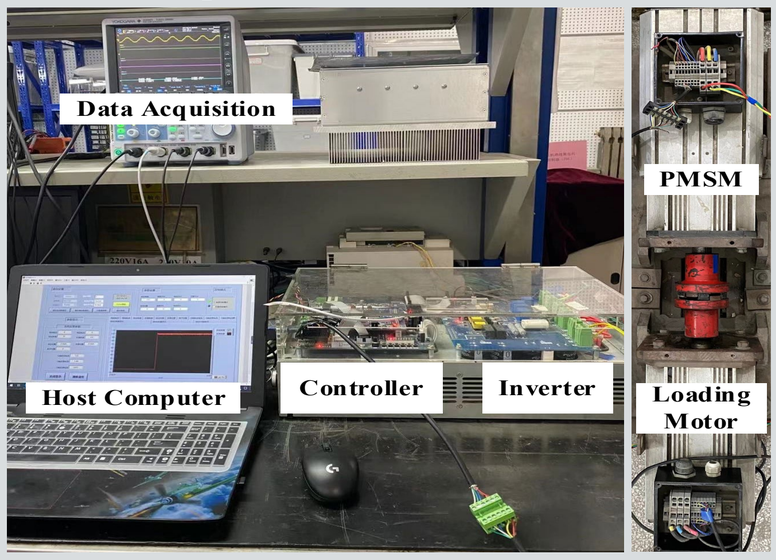
Acting time re-allocation of SVPWM

- Re-allocate the PWM driving signal for the post-fault inverter

Post-fault current control strategy

- Adapt the control reference to the post-fault system, so as to maximumly maintain the output speed and torque constant.

4 Experimental Verification

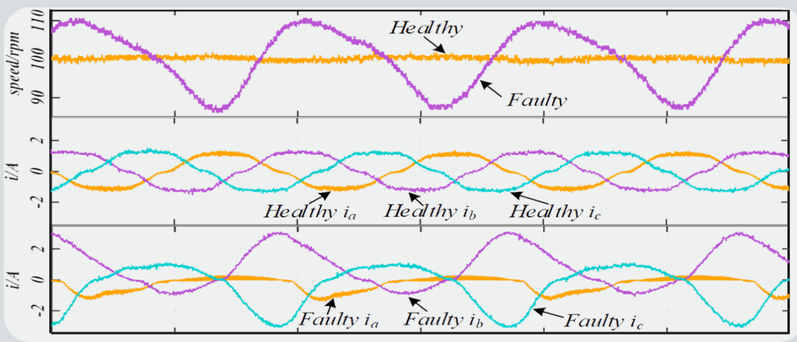


a Experimental Setup

A standard 25 A/1800 V IGBT based standard 3-ph 2-level motor drive;

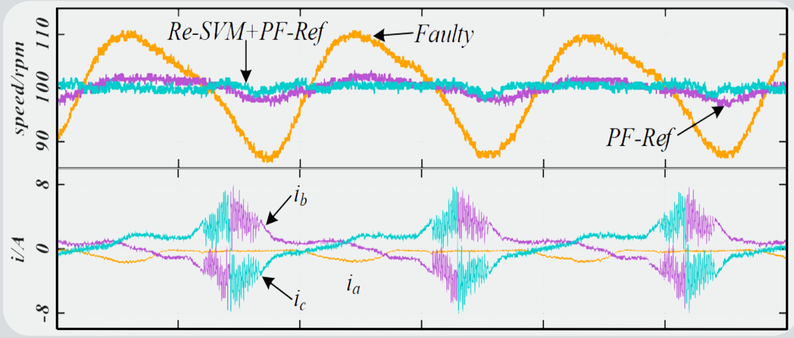
Two 18 kW Permanent Magnet Synchronous Motors;

Resolver and Hall sensors for position and current feedback



b Fault Influence

Single Open-circuit fault poses speed and torque fluctuations and increases current



c Effect of Proposed Limp-Home Strategy

The proposed method largely eliminates the fluctuation with a tolerable current increase

5 New Findings

- With the increasing occupancy and aging of EV, its safety can be improved by updating the control method of its standard powertrain.
- Inverter open-circuit faults can be incurred by various reasons and deprive EVs of their post-fault drivability.
- Employing the proposed method, the speed fluctuation is **reduced by 91.7%** and the duration of torque loss is **reduced by 92.9%**, but a derating operation is required due to the post-fault current.

6 Impact

Academia: Two technical papers have been published based on this topic and further improvement is ongoing.

Z. Zhang, Y. Hu, "An Embedded Fault-Tolerant Control Method for Single Open-Switch Faults in Standard PMSM drives", IEEE Trans. on Power Electron., 2022
Z. Zhang, etc, "A Hybrid Diagnosis Method for Inverter Open-Circuit Faults in PMSM Drives", CES Trans. on Electric. Machi. and Sys., 2020

Industry: Involved in a joint project with Group Lotus to be embedded in the software of their future inverters.