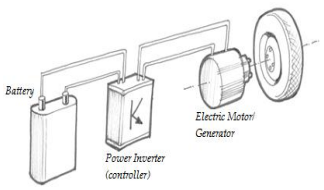
Enhanced Improvement Of Vehicle Dynamic Behaviour By Applying Torque Vectoring

Viewed From The Vehicle Dynamic And Powertrains Perspective

Graduates:
HAN University
S. Nada
S.J. Koster

Company:
TNO Automotive
S.T.H. Jansen
L.J.M. van Eeuwijk

Contact:
TNO Automotive
Steenovenweg 1
5708 HN Helmond
T 088 866 57 29
sven.jansen@tno.nl



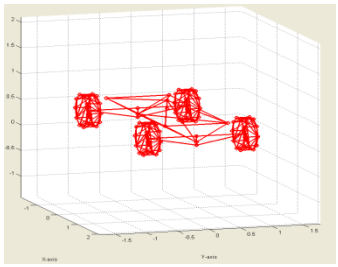
The primary (main) components of an Electric Vehicle powertrain [1]

Introduction and objective.

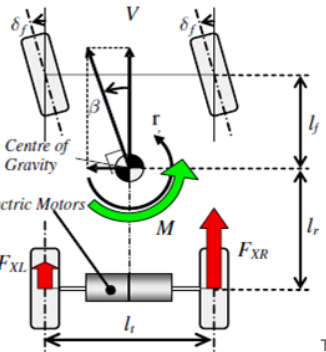
Study is conducted on a fully electric vehicle equipped with individual electric motors applied on the rear axle. When applying Torque Vectoring (TV) an extra yaw-moment will be applied on the vehicle which will help to steer and control the vehicle during under- and oversteer situations. This study will function as a fundament for the construction of a Torque Vectoring CarLab (test vehicle) and the modification to the Tyre Estimator® to cope with TV.

Approach and Results.

To study the vehicle behaviour when applying TV, a vehicle model is designed in MATLAB® SimMechanics®. To apply TV, an Direct Yaw Moment (DYM) controller is created.



Vehicle model designed in MATLAB® SimMechanics®



Target vehicle model [2]

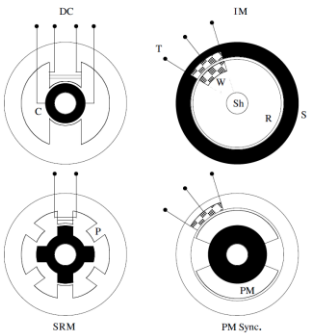
This controller strives to minimise the deviation between the vehicles yaw-rate $[r]$ and the calculated target yaw-rate;

$$r_{target} = \frac{g \cdot V_x \cdot \delta_f}{\eta \cdot V_x^2 + g \cdot L}$$

Aiming to keep the vehicle stable in all situations, a Traction (TR) controller is created and a Drive Force Limitation (DFL) controller is recommended.

Conclusions and Recommendations.

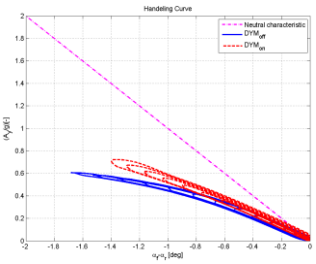
The Induction motor is considered particularly well suited when applying Torque Vectoring. This because it is very robust and it can adjust its magnetic field strength extending the control capabilities.



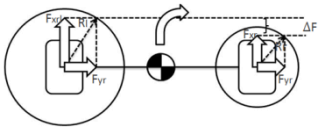
Cross sections of the Direct Current (DC), Induction (IM), Switch Reluctant (SRM) and Permanent Magnet Synchronous (PM Sync) Motors [3]

Simulation results show that the main improvement of applying Torque Vectoring is that the steer characteristic of the vehicle moves more toward a linear steer characteristic.
Also by applying a shift in longitudinal tyre forces, the inner rear wheel will have more margin to transfer lateral tyre forces.

r	Velocity
β	Slip Angle
ξ_f	Yaw Rate
l_f	Length from C.G(*) to front tyre
l_r	Length from C.G(*) to rear tyre
l_t	Tread
M	Yaw Moment
F_{XL}	Driving force on left side
F_{XR}	Driving force on right side
δ_f	Steering Angle

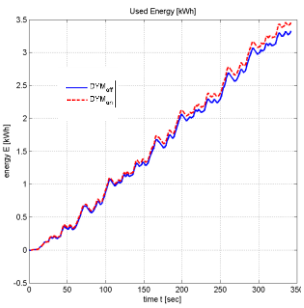


The steer characteristic with and without Torque Vectoring. Understeer is maintained keeping the vehicle stable



Friction circles rear tyres when applying TV [4]

A strong conclusion about the difference in consumption with and without TV, cannot be drawn because it strongly dependents on the operating points of the electric motor. Simulation results showed that the energy consumption may increase or decrease by as much as 1%.



Example of the used energy with and without Torque Vectoring.

To ensure that the Tyre Estimator®, a program developed by TNO to generate axle characteristics, can cope with TV, additions have to be made. The motor torque need to be measured so the extra yaw-moment due to TV can be calculated. Additionally the vehicle models inside the Tyre Estimator® need to be modified to apply this extra yaw-moment on the z-axis (perpendicular to the road) of the vehicle model.

[1] http://www.allaboutcircuits.com/vol_2/chpt_13/6.html. [Accessed 28 Oktober 2011].
[2] T. Sugano, H. Fukuba and T. Suetomi, "Vehicle System Dynamics," Hiroshima Japan, Oktober, 2010.
[3] L. Guzzella and S. Antonio, "Vehicle Propulsion Systems," Springer Berlin Heidelberg, Zürich, Switzerland, 2005.
[4] L. J.M. v. Eeuwijk, "Control of Active Electronic differential in Formula Student Electric Race Car," Eindhoven, TU/e, 2010.

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