# Summary

Motivated by the increasing energy prices in the late 1990's and the growing, worldwide awareness of the importance of sustainability, the demand for low fuel consumption and $CO_2$-emission vehicles increased greatly.

Recent developments at Innas B.V. have resulted in high-efficiency hydraulic motors, pumps and transformers. These components allow the design of a series hydraulic hybrid vehicle, the Hydrid. The Hydrid system enables the Internal Combustion Engine (ICE) to operate in on/off mode at peak efficiencies and is capable of delivering high power to the wheels. On/off-operation of the ICE avoids the deep part-loading conditions normally responsible for a large amount of power loss in the engine.

On/off-operation of the ICE allows the ICE to alternate between high power and complete shutdown. The average power output remains equal, but the ICE is able to operate at much higher efficiencies.

To allow on/off-operation, a Common Pressure Rail (CPR) with hydraulic accumulators is used to temporarily store the excess energy generated by the ICE. The CPR produces a near-constant pressure difference. This pressure is converted with a hydraulic transformer developed by Innas B.V. (IHT) to a pressure suitable for the high-efficiency hydraulic motor(s) to drive the vehicle.

To avoid part-loading at the secondary (load) side, driving regimes are introduced. The driving regimes are similar to gearshifts in a mechanical transmission and are used to force the driving units in more favourable operating conditions. The driving regimes are, however, not limited to solely varying the transmission ratio.

The hydraulic motors operate at high efficiencies at many operating conditions. Inefficiencies occur primarily at very low torque operation. Different methods can be used to avoid low-torque operation.

The possible configurations of hydraulic and mechanical components are determined by a design method known as "Creative Design". The method of switching between the different driving regimes is mostly independent of the method of creating the regimes. This results in a matrix of possible solutions. Additionally, the inherent lower efficiency of the hydraulic components compared to a pure mechanical driveline results in lower efficiencies at high vehicle speeds. Different methods are available of driving at high speeds. Viable variants in this matrix are evaluated and weighted on fuel consumption, investment cost, comfort, weight and required space-use.

The most promising topology is considered to be a relatively simple configuration of a secondary drive unit piggybacked to a primary drive unit. Mechanical decoupling of the auxiliary drive unit using a double acting clutch results in both low investment and fuel costs. Qualitative evaluation suggest that the comfort level of this topology is acceptable.

Fuel consumption can be further lowered by installing a parallel mechanical driveline, directly connecting the ICE to the differential. This results in a transmission ratio between a $4^{th}$ or $5^{th}$ gear in a conventional vehicle without losses normally encountered in the gearbox.

To determine the key points of interest of the double-position clutch design, a first step of a detailed analysis is made. A model of the system dynamics is used to simulate the behaviour of the hydraulic system and vehicle during clutch engagement. The two aspects of the hydraulic system are

investigated are the speed-up of the secondary motor during clutch engagement and the effect of the clutch engagement on the overall hydraulic circuit and components.

It is expected that applying pressure to the secondary drive unit during clutch engagement results in possible hazardous acceleration of the drive unit above its design limits.

The behaviour of the hydraulic configuration is different than initially expected. The speed-up of the secondary drive unit is limited as the initial acceleration of the unit causes an increased flow rate from the hydraulic line. The net flow out of the hydraulic line causes a rapid decrease in pressure. The IHT only increases its operational speed (and thus flow rate) as a delayed response to the decreased pressure.

It can be concluded that accurate matching of the IHT setting and clutch pattern is important. When the secondary drive unit is accelerated rapidly by the hydraulic pressure, over-speeding may cause speeds in excess of the design limits of the unit. When clutch engagement is very short a large decrease in pressure may cause cavitation in the hydraulic line.