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Settings for proposed Transmission Control Unit for VECTO

In this documentation the settings and input parameters are described, to adjust the proposed Transmission Control Unit (TCU) for the desired gearshift behaviour.

The settings are defined in the script `...\b_load_input_data\b100_input_TCU.m`, which was part of Scania's upload from 3 Sep 2018 to the official web space for VECTO [1].

Here the parameters are listed in the order of appearance in `b100_input_TCU.m`.

`GearChangeTime [s]`

Duration of traction interruption during gearshift.

`GearResTime [s]`

Minimum residence time in the new gear after the current gearshift. The next gearshift will not be initiated before the HDV model ran at least for this time in the shifted gear.

`AllowedGearRangeUp [-]`

Range of permitted gears for upshifts. If `AllowedGearRangeUp` was set to "3" and the current gear is 4, the next upper gear may be max. 7.

`AllowedGearRangeDown [-]`

Range of permitted gears for downshifts. If `AllowedGearRangeDown` was set to "2" and the current gear is 8, the next lower gear may be min. 6.

`DelayShift [s]`

The minimum time between any gearshift (up, down) and the subsequent gearshift (up, down).

`DelayUpDown [s]`

The minimum time between an upshift and the subsequent downshift.

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[1] https://webgate.ec.europa.eu/CITnet/jira/browse/VECTO-578
attachment 2018-07-13_Prototype-TCU-VECTO_R2016a.zip

`DelayDownUp [s]`

The minimum time between a downshift and the subsequent upshift.

`duration_look_back_P_card [s]`

Duration of the look-back period, during which the average of the past cardan power is calculated.

Details: The TCU contains two separate shifting modes. The main mode is the efficiency-based gearselection for traction, during phases of positive cardan power. For coasting and braking, during phases of negative cardan power, a simple gearselection based on thresholds for the engine speed gets active.

To avoid oscillating changes between the two modes, during coasting at very small positive and negative current cardan powers, the average past cardan power is calculated.

There are two possibilities to change the shifting mode from traction to coasting/braking. First, if the average past cardan power gets above its threshold (`P_card_avrg_past_pos`, see below). Second, if the instantaneous current cardan power gets above its threshold (`P_card_curr_pos`, see below). If e. g. after a longer coasting section an immediate acceleration is demanded and the cardan power increases, the average past cardan power can still be below `P_card_avrg_past_pos`, but its current value already above `P_card_curr_pos`, so the TCU will change to the mode for traction.

There is one possibility to change the shifting mode from traction to coasting/braking. If the average past cardan power gets below its threshold, the shifting mode for coasting/braking is chosen.

In addition `duration_look_back_P_card` is used to define, if the TCU shall be in traction mode for driveaway. If the simulated velocity during this period was zero, a driveaway took part shortly before and the TCU remains in traction mode.

`no_timesteps_look_back_P_card [-]`

Due to the implementation in Simulink the number of timesteps to look-back was necessary to calculated the average past cardan power.

`P_card_avrg_past_pos [kW]`

If the average past cardan power gets below this threshold, the TCU changes to the shifting mode for coasting/braking, see above in the details for `duration_look_back_P_card`.

`P_card_curr_pos [kW]`

If the instantaneous current cardan power gets below this threshold, the TCU changes to the shifting mode for coasting/braking, see above in the details for `duration_look_back_P_card`.

`StartupVelocity_dem_kmh [km/h]`

Only for the gearselection at driveaway: The velocity of the vehicle model.

At the timestep before driveaway, where the gear needs to be selected, no predicted velocity is available, because the current velocity is zero, at the end of the present stop.

`StartupVelocity_dem_kmh` is only used in the separate mode for driveaway.

`StartupAcc [m/s²]`

Only for the gearselection at driveaway: The acceleration to calculate the inertia force of the vehicle model.

`StartupAcc` is only used in the separate mode for driveaway.

`share_idle_low_y_axis [-]`

Where:	$n_{eng,accept,low}$	Lowest acceptable engine speed
	n_{idle}	Engine idle speed
	n_{P99H}	Max. engine speed, where 99 % of the max. engine power are reached.

Determination of $n_{eng,accept,low}$, y-axis for interpolation (→ dependent variable, output).

Share at the distance from n_{idle} to n_{P99H}.

$n_{eng,accept,low} = n_{idle} +$ `share_idle_low` $* (n_{P99H} - n_{idle})$

`v_veh_sim_curr [km/h]`

Determination of $n_{eng,accept,low}$, x-axis for interpolation (→ independent variable, input).

Simulated vehicle velocity in current timestep.

Details: At velocities between 0 and 20 km/h the min. acceptable engine speed is lowered, to avoid unnecessary downshifts.

`Dn_Tq99L_high_min_1 [-]`

Where: $n_{eng,accept,high,min}$ Minimum of the highest acceptable engine speed for the current gear
n_{Tq99L} Min. speed where 99 % of the max. engine torque are reached

The low limit for $n_{eng,accept,high,min}$.
Low share at the distance from n_{Tq99L} to n_{P99H}, as example set to 40 %.

Details: There is a minimum and a maximum for $n_{eng,accept,high,min}$, and the minimum itself is limited to a low and high value.

`Dn_Tq99L_high_min_2 [-]`

Where: n_{Tq99H} Max. engine speed where 99 % of the max. engine torque are reached.

The high limit for $n_{eng,accept,high,min}$.
High share at the distance from n_{Tq99L} to n_{P99H}, as example set to 50 %.
$n_{eng,accept,high,min}$ = max{ min(n_{Tq99H} ; `Dn_Tq99L_high_min_2`) ; `Dn_Tq99L_high_min_1` }

Details: With the example values for `Dn_Tq99L_high_min_1` and `Dn_Tq99L_high_min_2` it is defined, that $n_{eng,accept,high,min}$ for the current gear is always between 40 to 50 % of the distance from n_{Tq99L} to n_{P99H}.
This definition for $n_{eng,accept,high,min}$ results in values near n_{Tq99H}, but avoids too low or too high limits, if n_{Tq99H} should be located left or right of this speed range.

`Ratio_Tq_card_dem_const_vect [-]`

Where: $n_{eng,accept,high}$ Highest acceptable engine speed for the current gear
$Tq_{card,const}$ Necessary cardan torque for *constant velocity* at the predicted road gradient
$Tq_{card,max,curr}$ Max. possible cardan torque in the current gear at the predicted engine speed

Determination of $n_{eng,accept,high}$, x-axis for interpolation (→ independent variable, input).
Share of $Tq_{card,const}$ at $Tq_{card,max,curr}$, what is the ratio ($Tq_{card,const}$ / $Tq_{card,max,curr}$).
If the ratio exceeds a certain limit, $n_{eng,accept,high}$ is increased from $n_{eng,accept,high,min}$ to a speed between $n_{eng,accept,high,min}$ and n_{P99H}.

`Ratio_w_eng_curr_max_vect [-]`

Determination of $n_{eng,accept,high}$, y-axis for interpolation (→ dependent variable, output).
Share of distance from $n_{eng,accept,high,min}$ to n_{P99H}.
$n_{eng,accept,high}$ = $n_{eng,accept,high,min}$ + `Ratio_w_eng_curr_max_vect` * (n_{P99H} – $n_{eng,accept,high,min}$)

Diff_curr_targ_vel [-]

Where: $\Delta v_{curr,targ,rel}$ Relative deviation of currently simulated velocity to target velocity, $\Delta v_{curr,targ,rel} = \min\{ (v_{curr} - v_{targ}) / v_{targ} ; 0 \}$

a_{rsrv} Acceleration reserve

v_{targ} Target velocity for vehicle model, velocity to be reached

v_{curr} Currently simulated velocity

Determination of a_{rsrv}.

Diff_curr_targ_vel is the denominator for the x-value (→ independent variable, input) for the interpolation of a_{rsrv}. It is the lower limit for $\Delta v_{curr,targ,rel}$, where a_{rsrv} becomes biggest.

The x-value for the interpolation of a_{rsrv} is min{ $\Delta v_{curr,targ,rel}$ / Diff_curr_targ_vel ; 1 }.

a_rsrv_Dv_targ_curr_low [m/s²]

Determination of a_{rsrv}, y-axis for interpolation (→ dependent variable, output).

If the ratio ($\Delta v_{curr,targ,rel}$ / Diff_curr_targ_vel) gets very small, the HDV model is very close to the target velocity. In this case the interpolated acceleration reserve is very close to the values from a_rsrv_Dv_targ_curr_low.

..._low for low values of the acceleration reserve.

a_rsrv_Dv_targ_curr_high [m/s²]

Determination of a_{rsrv}, y-axis for interpolation (→ dependent variable, output).

If the ratio ($\Delta v_{curr,targ,rel}$ / Diff_curr_targ_vel) gets close to 1, the HDV model gets significantly slower than required by the target velocity. In this case the interpolated acceleration reserve gets close to the values from a_rsrv_Dv_targ_curr_high.

..._high for high values of the acceleration reserve.

v_veh_sim_curr [km/h]

Determination of a_{rsrv}, x-axis for the interpolation (→ independent variable, input).

Details: During the simulation a_rsrv_Dv_targ_curr_low and a_rsrv_Dv_targ_curr_high are inpolated from the respective curves, with v_veh_sim_curr as input.

Afterwards a_{rsrv} is linearly interpolated by

a_{rsrv} = a_rsrv_Dv_targ_curr_low + min{ $\Delta v_{curr,targ,rel}$ / Diff_curr_targ_vel ; 1 } * ...
(a_rsrv_Dv_targ_ curr_high − a_rsrv_Dv_targ_curr_low)

In the example `a_rsrv_Dv_targ_curr_low` is set to small negative values at $v_{curr} \geq 60$ km/h.

This means: If the HDV model is close to or at v_{targ} on motorways, the gears incl. the current one are rated for the cardan torque as if a slight *deceleration* would be accepted. This turned out to be necessary for simulating motorway cycles when the road gradient increases slowly, e. g. when entering a rise or passing a crest.

Without an accepted small deceleration ($a_{rsrv} < 0$) the TCU would immediately shift down, when the predicted cardan torque from ($a_{rsrv} \geq 0$) gets higher than possible in the current gear. With the deceleration ($a_{rsrv} < 0$) the TCU shift down only, when v_{curr} gets significantly below v_{targ}.

So this function avoids aggressive downshifts at small rises during motorway simulation.

`Lookback_driver [s]`

Smoothening of the driver acceleration.

Duration of the look-back period, to calculate the average, smoothened driver acceleration.

Because the acceleration from the driver submodel in the Simulink vehicle model showed occasionally an oscillating behaviour, it was smoothened as input for the TCU.

`no_dt_driver [-]`

Due to the implementation in Simulink the number of timesteps to look back was necessary to calculated the average past driver acceleration.

`a_driver_threshold [m/s²]`

The threshold to feed through the smoothened driver acceleration to the TCU. If the smoothened driver acceleration is below this threshold, the input to the TCU is 0.

`Dt_pred_vs_Dt_shift [-]`

Where:	Δt_{pred}	The duration to look forward into the hypothetical gearshift interval.
	Δt_{shift}	The duration of a gearshift interval, i. e. the duration of traction interruption. VECTO settings: 0 s for APT, 1 s for AMT, 2 s for SMT.
	$v_{post\text{-}sh}$	The estimated vehicle velocity post-shift, after the traction interruption which took place during a hypothetical gearshift.
	v_{pred}	Predicted vehicle velocity for the gear rating

Determination of the share of the prediction duration at the gearshift duration. y-axis for interpolation (→ dependent variable, output)

During every timestep the TCU looks forward into a hypothetical gearshift interval, to estimate the predicted vehicle velocity.

It is `Dt_pred_vs_Dt_shift` = $\Delta t_{pred} / \Delta t_{shift}$.

v_{pred} is then calculated via $v_{pred} = v_{curr}$ + `Dt_pred_vs_Dt_shift` * ($v_{post\text{-}sh} - v_{curr}$)

`v_postShift_vs_v_simCurrent [-]`

Where: $grad_{curr}$ Simulated road gradient in current timestep.

Determination of the share of the prediction duration at the gearshift duration. x-axis for the interpolation (→ independent variable, input).

During every timestep the TCU estimates $v_{post\text{-}sh}$ by 2D-interpolation from a look-up table with v_{curr} and $grad_{curr}$ as inputs to this table. The table was calculated during the preprocessing, and is individual for every single HDV configuration (vehicle mass, air drag, rolling resistance, drivetrain idle friction when engine declutched). The result from this table is $v_{post\text{-}sh}$: The estimated velocity after coasting up- or downhill during Δt_{shift}.

It is `v_postShift_vs_v_simCurrent` = $v_{post\text{-}sh} / v_{curr}$.

Details: If the HDV model would slow down significantly during a hypothetical gearshift, `v_postShift_vs_v_simCurrent` gets small. For these cases `Dt_pred_vs_Dt_shift` gets 1 (inpolated from its characteristic curve). That means v_{pred} becomes $v_{post\text{-}sh}$. If the HDV model would slow down less, v_{pred} is in the second half of the interval between v_{curr} and $v_{post\text{-}sh}$.

`share_Tq99L [-]`

Where: $Tq_{eng,max}$ Max. engine torque

$Tq_{eng,upper,post\text{-}sh}$ Available engine torque in upper gears post-shift, in the first timestep after the hypothetical gearshift.

Determination of the limited gradeability after upshifts, y-axis for interpolation (→ dependent variable, output).

For HDV models with very low power-to-mass ratios the gradeability after hypothetical upshifts is limited.

During tests with 60 t vehicle mass and weak engines it was found, that during the simulation of slow driving at steep uphill sections an upshift to <u>low</u> gears (gear 1 to 2, or 2 to 3) sometimes crashed the simulation. The TCU assumed the full available engine torque at the predicted operation points, what was not the case due to the turbo lag. The HDV model stopped.

The described case should occur only very seldom during certification, if at all. Nevertheless it shall be considered to avoid aborted simulations.

`share_Tq99L` is the share of $Tq_{eng,max}$, reduced by the turbo-lag. The reduced torque is assumed to be available at n_{Tq99L}, for low velocities and upshifts to low gears.

It is $Tq_{eng,upper,post\text{-}sh}$ = `share_Tq99L` * $Tq_{eng,max}$

`shareTq99L_v_axis [km/h]`

Where: $v_{n.Tq99L}$ Vehicle velocity, per gear at n_{Tq99L}

Determination of the reduced engine torque directly after a hypothetical gearshift, x-axis for the interpolation (→ independent variable, input).

Details:

- For every gear $v_{n.Tq99L}$ is calculated in the preprocessing, and serves as input for the interpolation of `share_Tq99L`.
- $Tq_{eng,upper,post-sh}$ is determined per gear.
- By calculating with n_{Tq99L} and $Tq_{eng,upper,post-sh}$ from engine to wheel, the max. traction force in the contact area between the powered wheels and the road is determined.
- After the subtraction of the air drag (for $v_{n.Tq99L}$ per gear) the traction force to overcome rolling resistance and gradient force during constant uphill driving remains.
- This force is used to calculate the road gradient per gear, which can be made after upshifts with reduced max. available engine torque, without stopping the HDV model.
- This driveable road gradient per gear is considered during the decision for or against an intended upshift.