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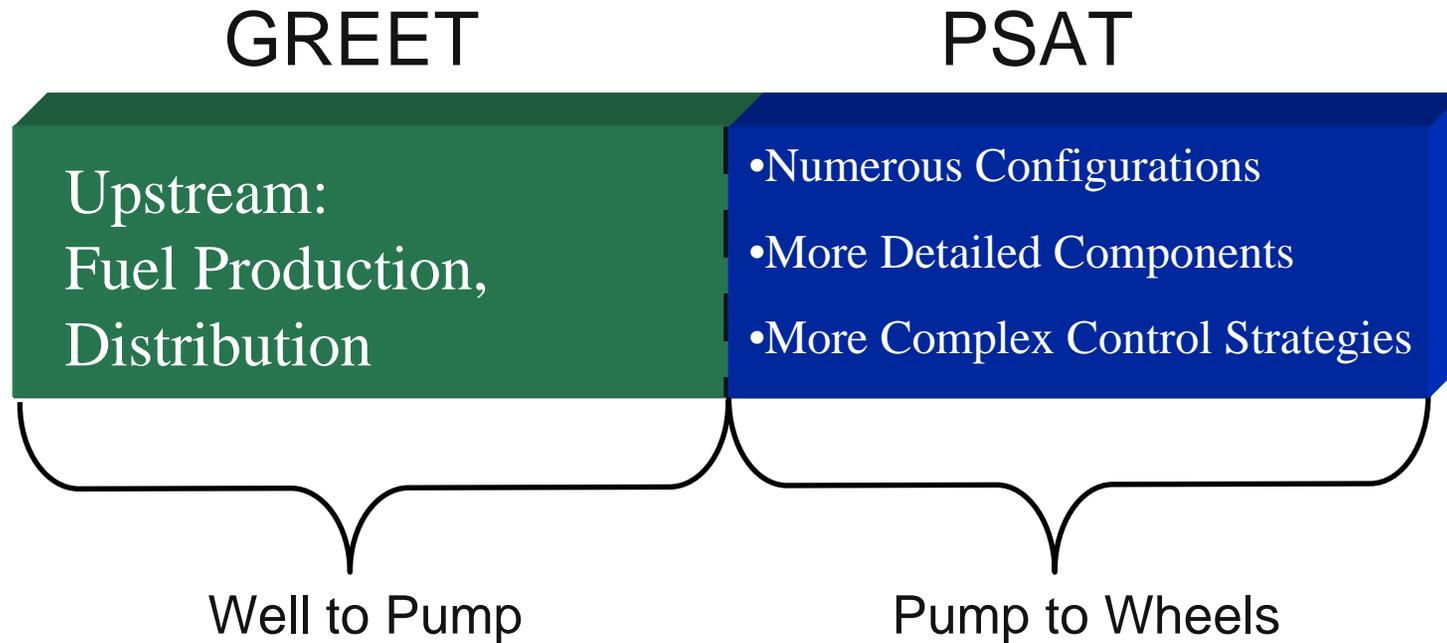
Designing Advanced Vehicle Powertrains Using PSAT

GREET Training
June 25, 2007

Aymeric Rousseau
Argonne National Laboratory



GREET and PSAT Are Synergetic Tools



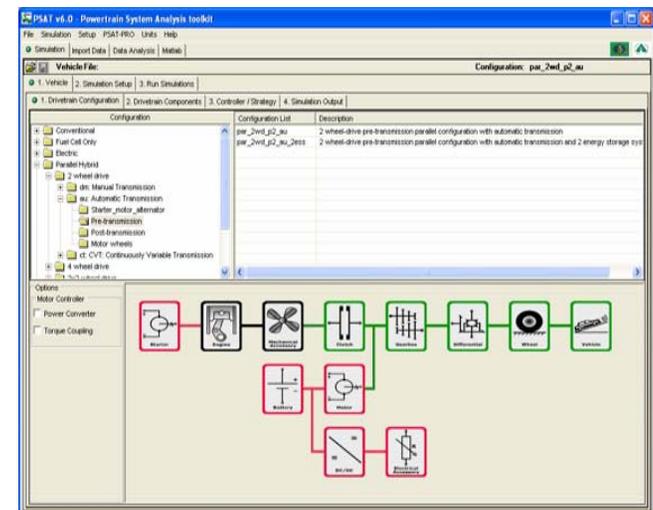
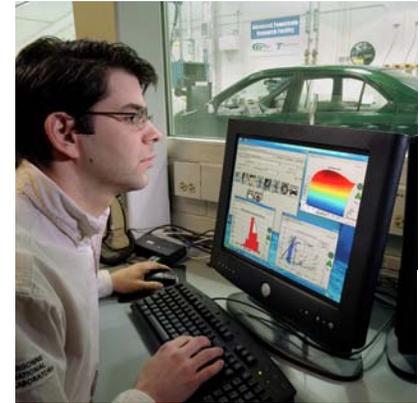
PSAT Simulations Support R&D and Management Decisions

- After a thorough assessment, PSAT has been selected in 2004 as the primary vehicle model for all FreedomCAR and 21 CTP activities by the U.S.DOE, stating that *“All future code development and enhancements for OFCVT shall focus on PSAT and PSAT-PRO”*
- PSAT has been awarded a R&D100 Award in 2004 represented to the 100 most technologically significant new products and processes introduced into the market each year.
- PSAT has been awarded a Technology Transfer Award in 2007
- *“... We need a model that’s intuitive, easy to use, and provides accurate results. PSAT gives us that.”* Randy Yost - GM Engineering Specialist

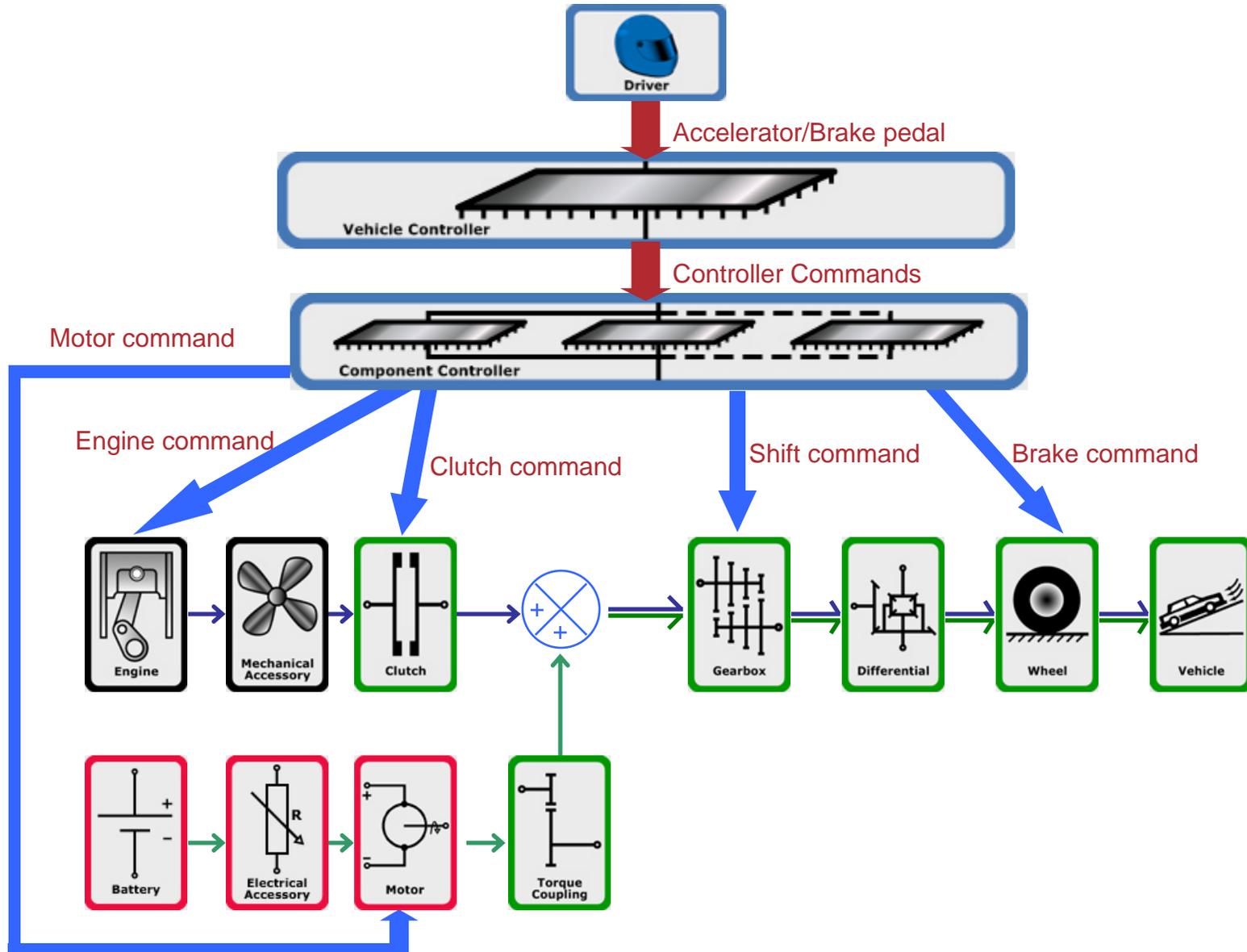


Developed to meet the requirements of automotive engineering throughout the development process

- Forward-looking model
- Wide range of vehicle applications from light to heavy duty
- Unrivalled number of predefined configurations
- Easy implementation of proprietary data, component models, control strategies or drive cycles
- Easy to use Graphical User Interface
- Possibility to use the control strategies for Hardware-in-the-Loop / Software-in-the-Loop
- Designed for co-simulation environment



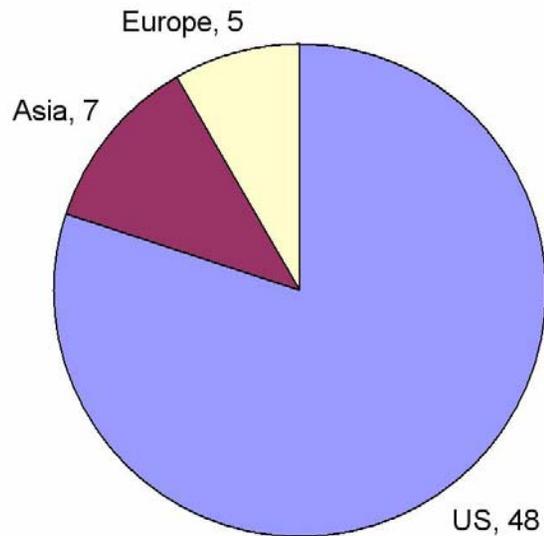
Forward Modeling Provides Accurate Results



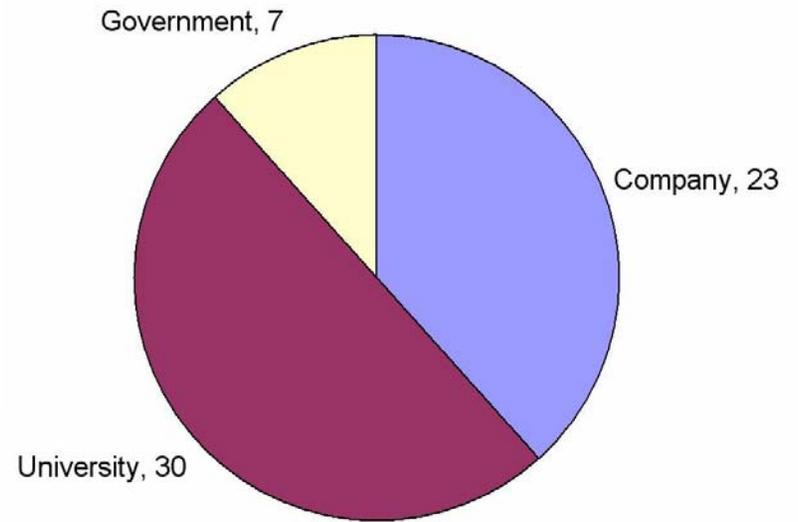
Large User Database Proof of Success



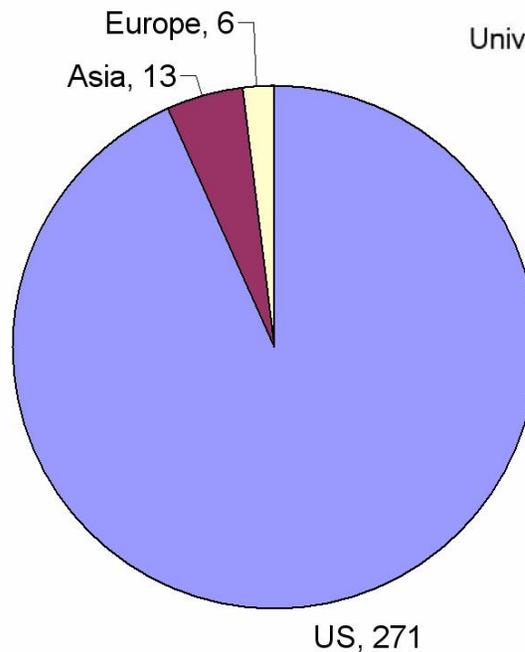
Numerous US Companies are Using PSAT



Licenses
Location Favors
US



Licenses
Distribution
Evenly Split



PSAT Close to
300 Users

As of December 2006

Different Users Have Different Needs

U.S.DOE

- Validated complete vehicle models
- Focused on fuel economy and performance
- Evaluate component in vehicle system context
- Evaluate fuel economy potential of future technologies (e.g. goals)

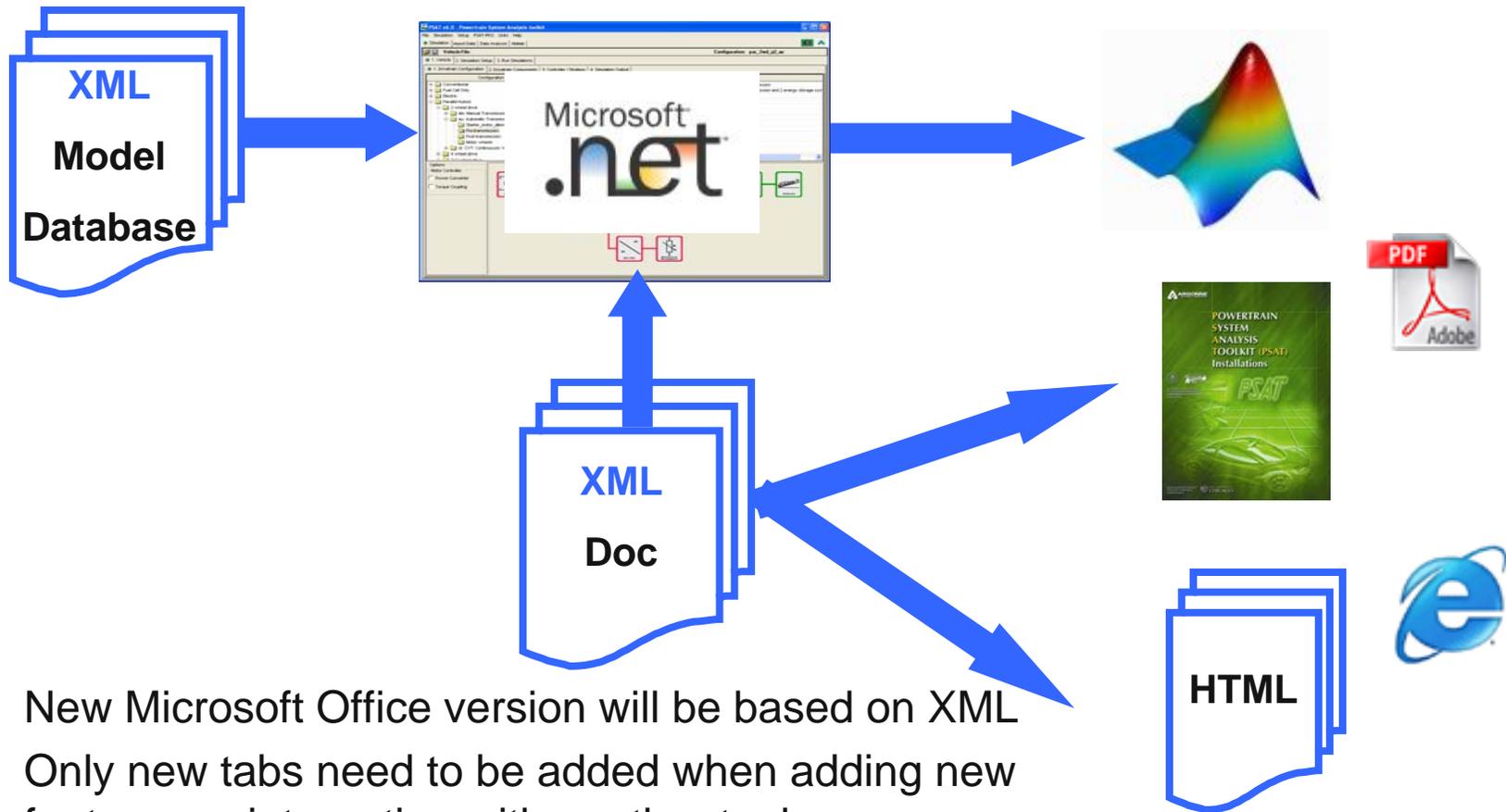
Car Companies

- Implement their own models/data/controls
- Also interested in drive quality & emissions
- Need to have different levels of modeling
- Interested in software architecture & post-processing tools

Suppliers

- Implement their component model / subsystems (reuse rest of PSAT models)
- Interested in software architecture & post-processing tools

PSAT Architecture Designed to Suit All Users Needs



- New Microsoft Office version will be based on XML
- Only new tabs need to be added when adding new features or integrating with another tool

PSAT - A Single Tool Throughout the Development Process

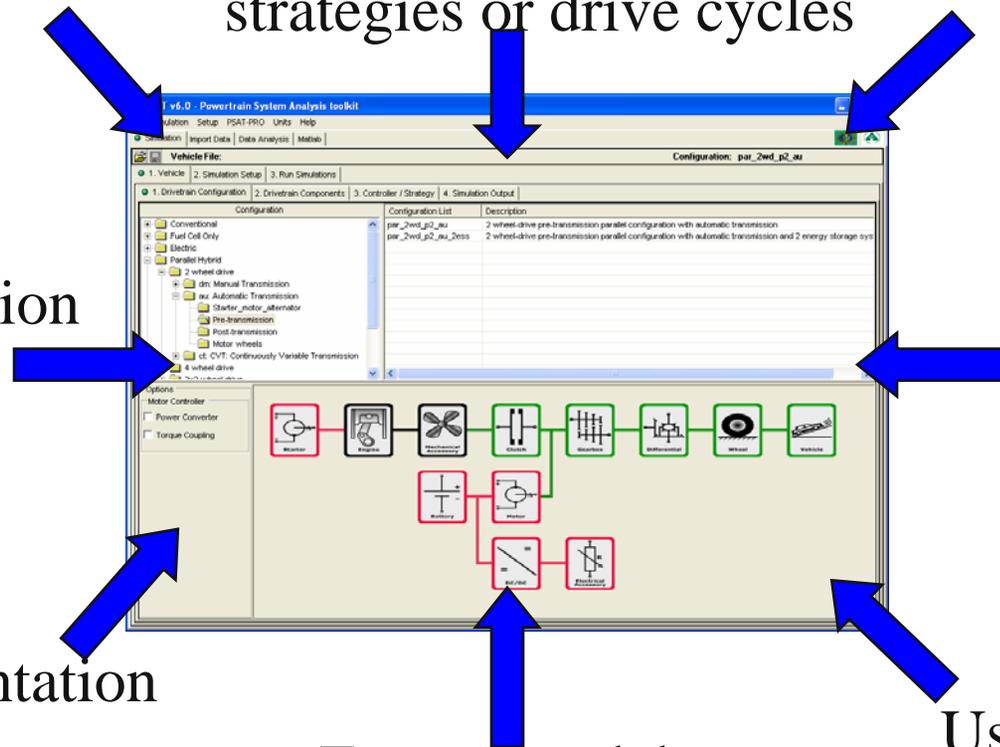
Build and compare large number of powertrain configurations

Easy selection of data, models, control strategies or drive cycles

Run batch mode

Ensure simulation traceability

Analyze and compare test and simulation data



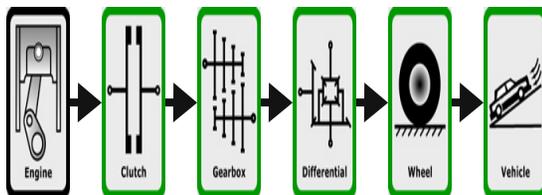
Easy implementation of data, models, control strategies or drive cycles

Ensure model compatibilities

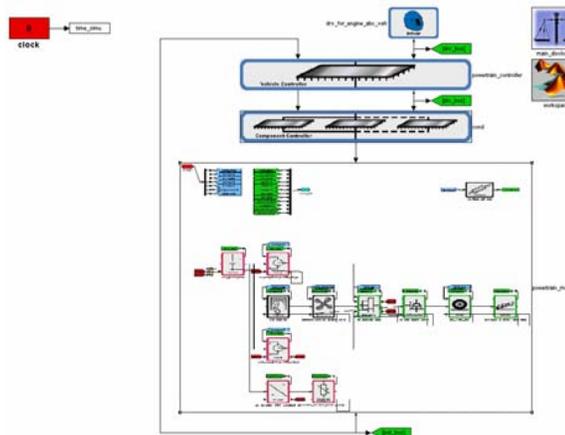
Use models and controls for HIL/RCP

Large Number of Configurations Achieved Through Automatic Building

Option #1
Drag & Drop



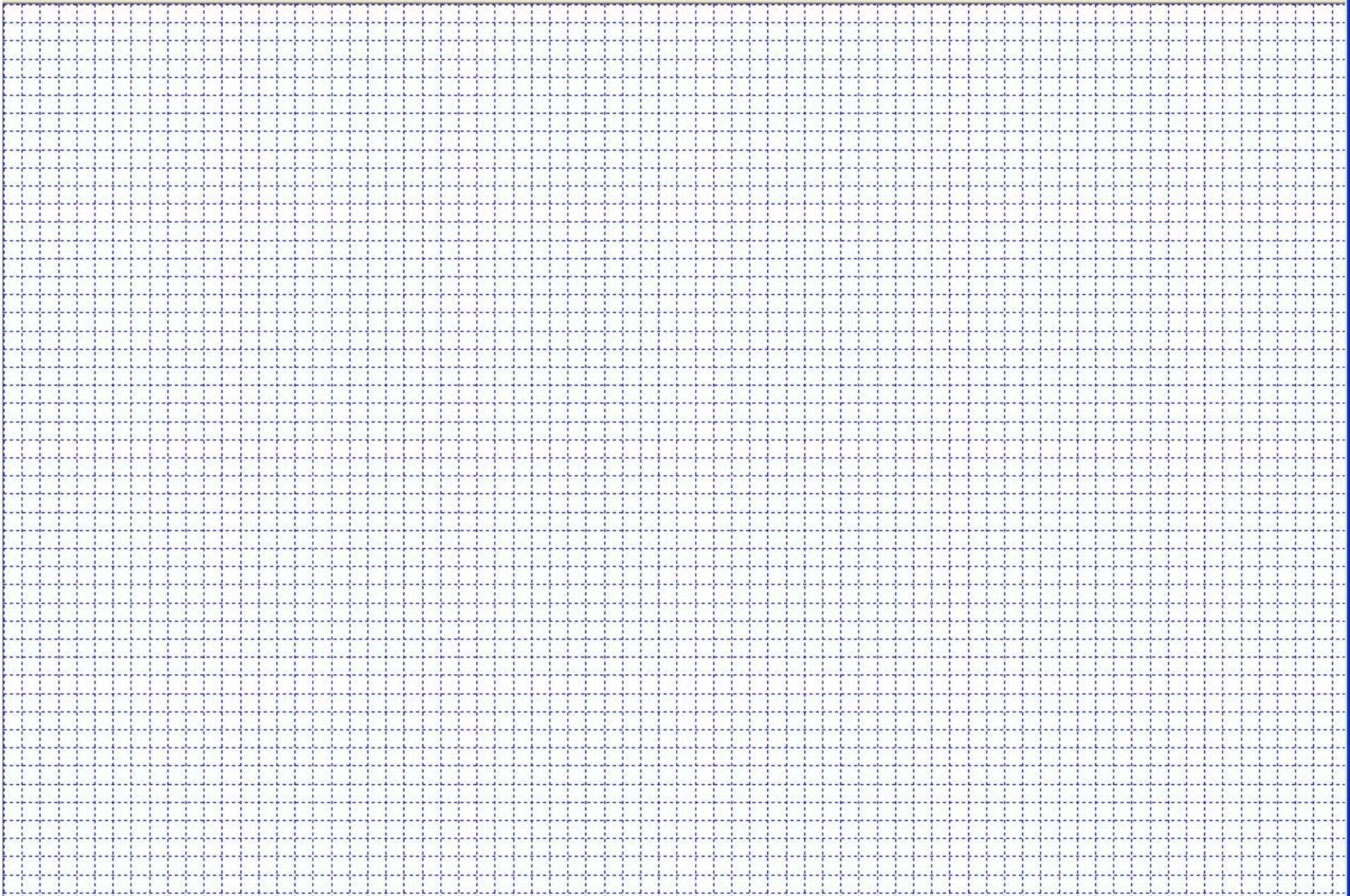
Option #2
Save Entire Vehicles



Solution
**Build
model
based on
users
choices
using
add_block
&
add_line**

split_2wd

File Edit View Simulation Format Tools Help



split_2wd *

File Edit View Simulation Format Tools Help

clock

time_simu

Vehicle Controller

pts_bus

main_blockofuse

powertrain_controller

Building The Simulink Model, Please Wait...

lib_powertrain_controller

File Edit View Simulation Format Tools Help

Vehicle Controller

powertrain_controller

Ready 100% ode45

start

Inbox... L:\Veh... AyR - ... MATLAB I:\mod... Simula... split_2... lib_po...

11:28 AM

split_2wd *

File Edit View Simulation Format Tools Help

clock

time_simu

Vehicle Controller

Component Controller

powertrain_controller

pts_bus

cond

main_hisocofute

Building The Simulink Model, Please Wait...

lib_cond

File Edit View Simulation Format Tools Help

Component Controller

cond_v01

Ready 100% ode45

start

Inbox...

L:\Veh...

AyR - ...

MATLAB

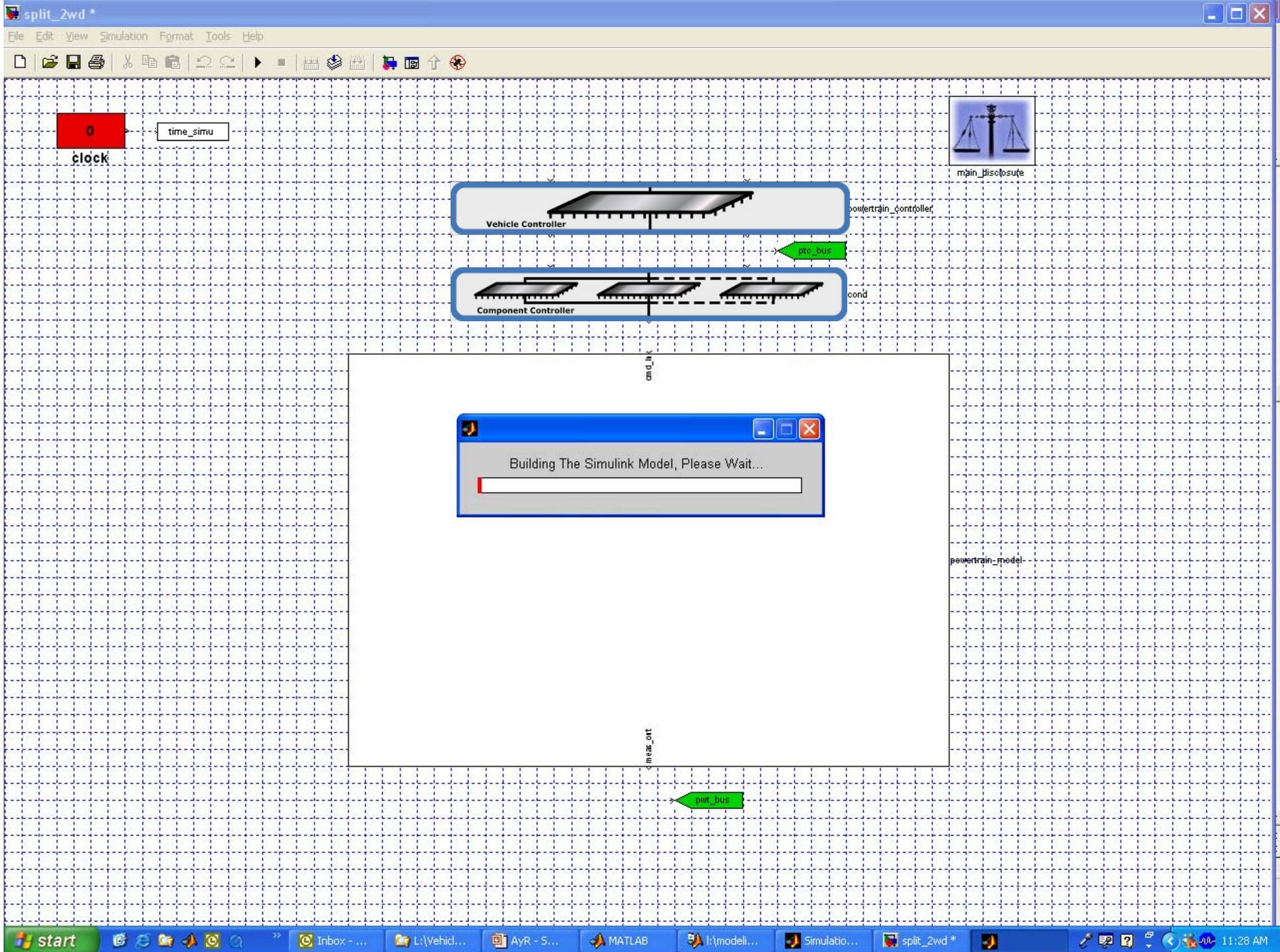
I:\mod...

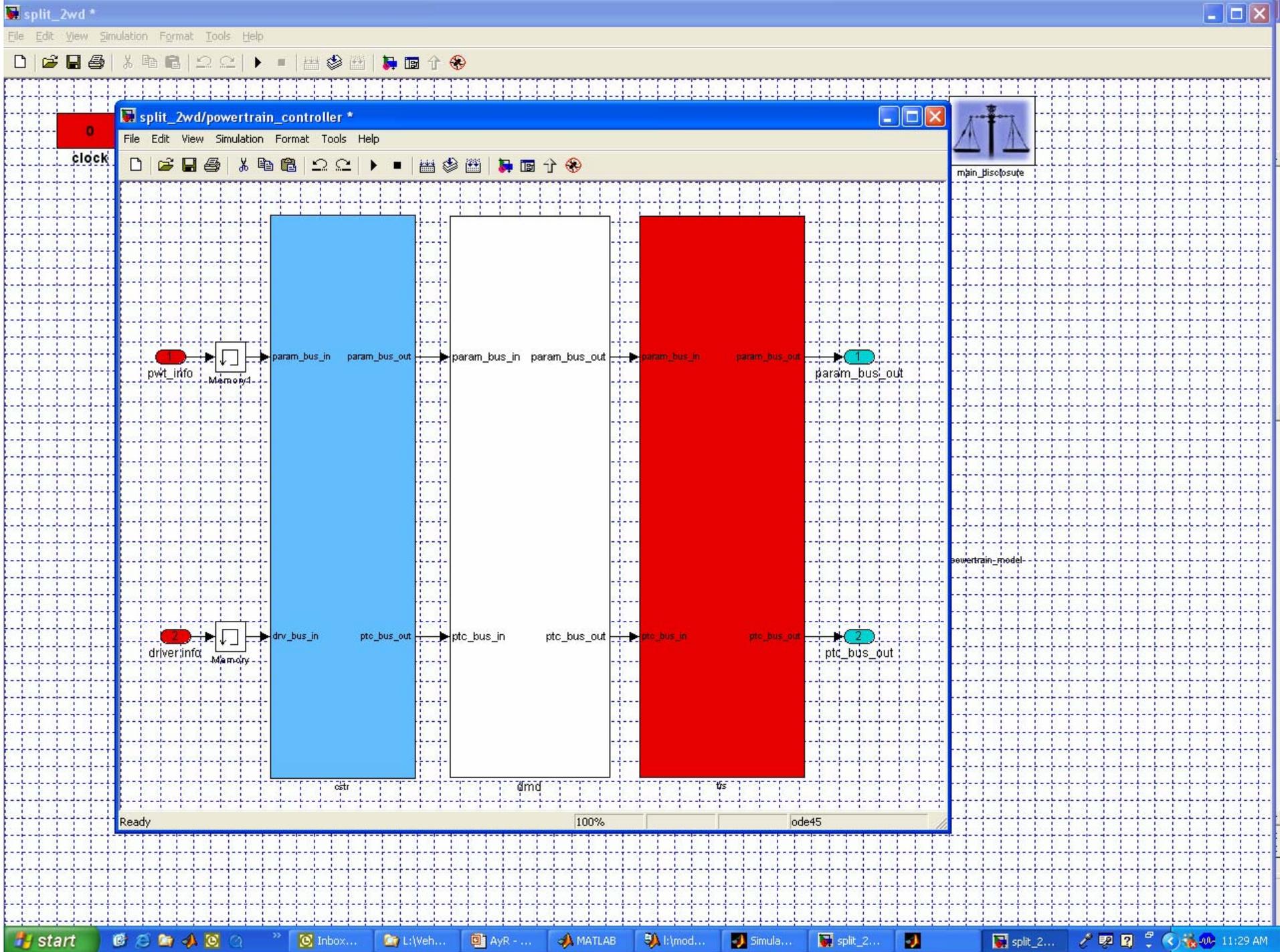
Simula...

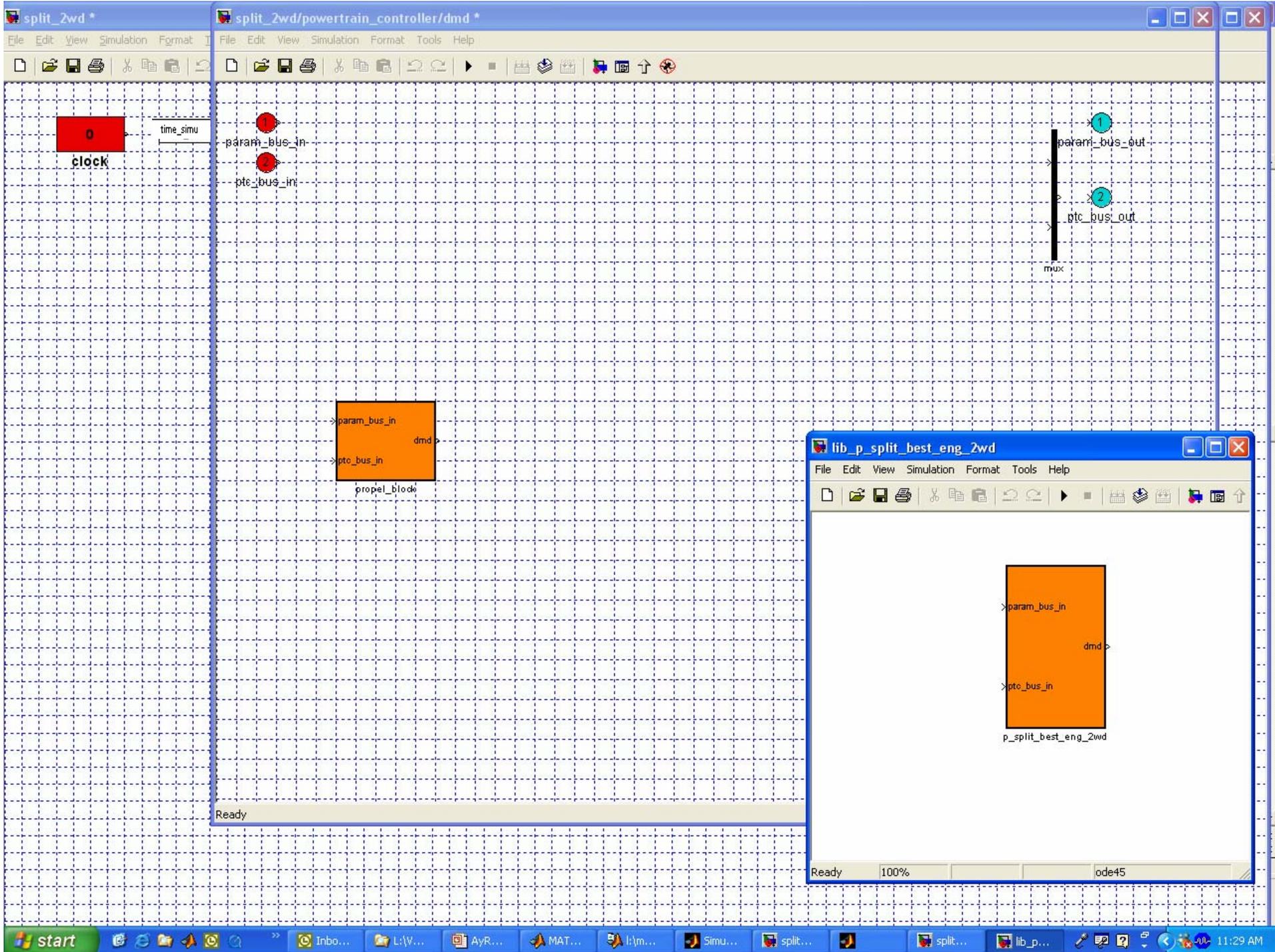
split_2...

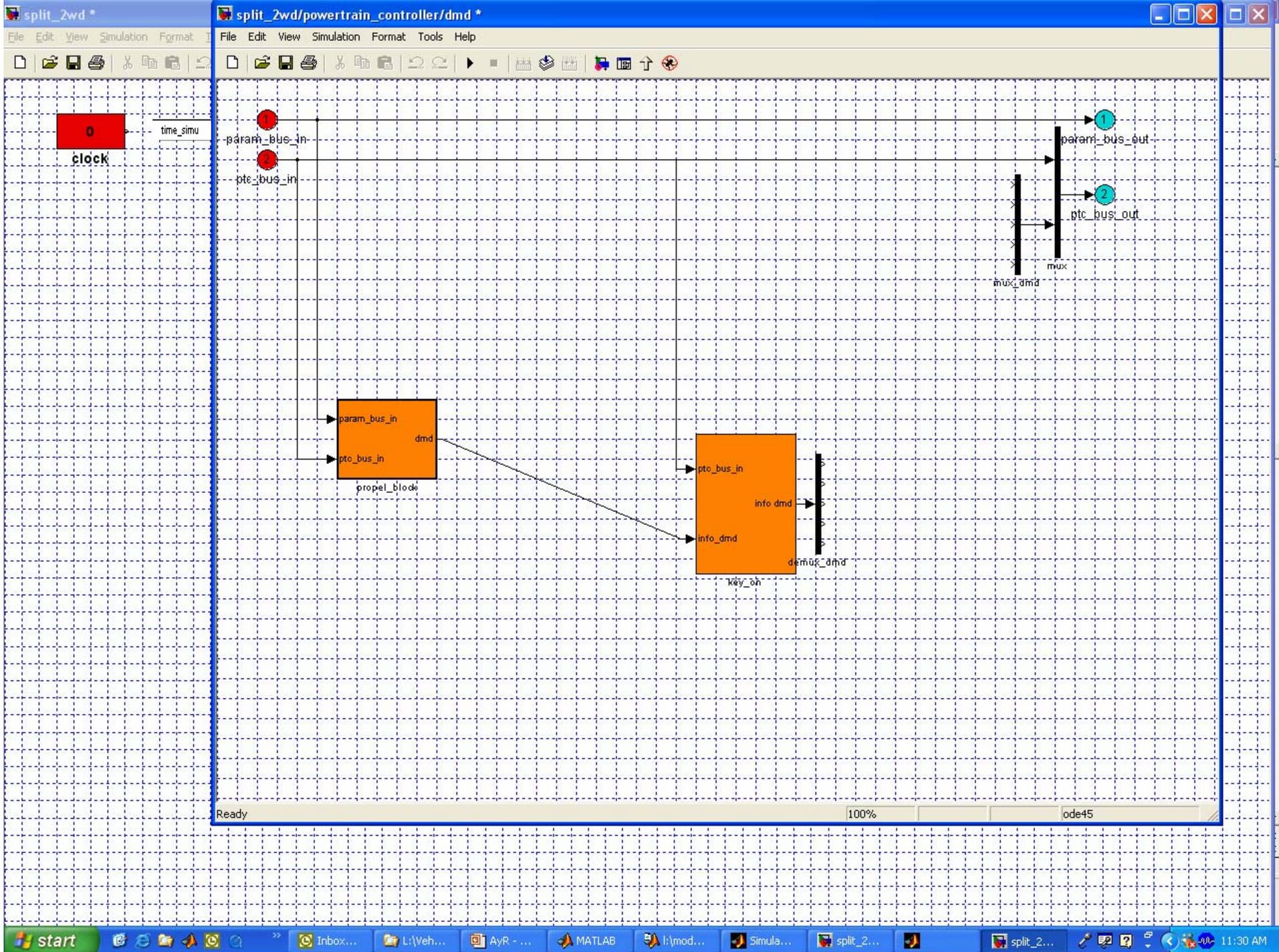
lib_cond

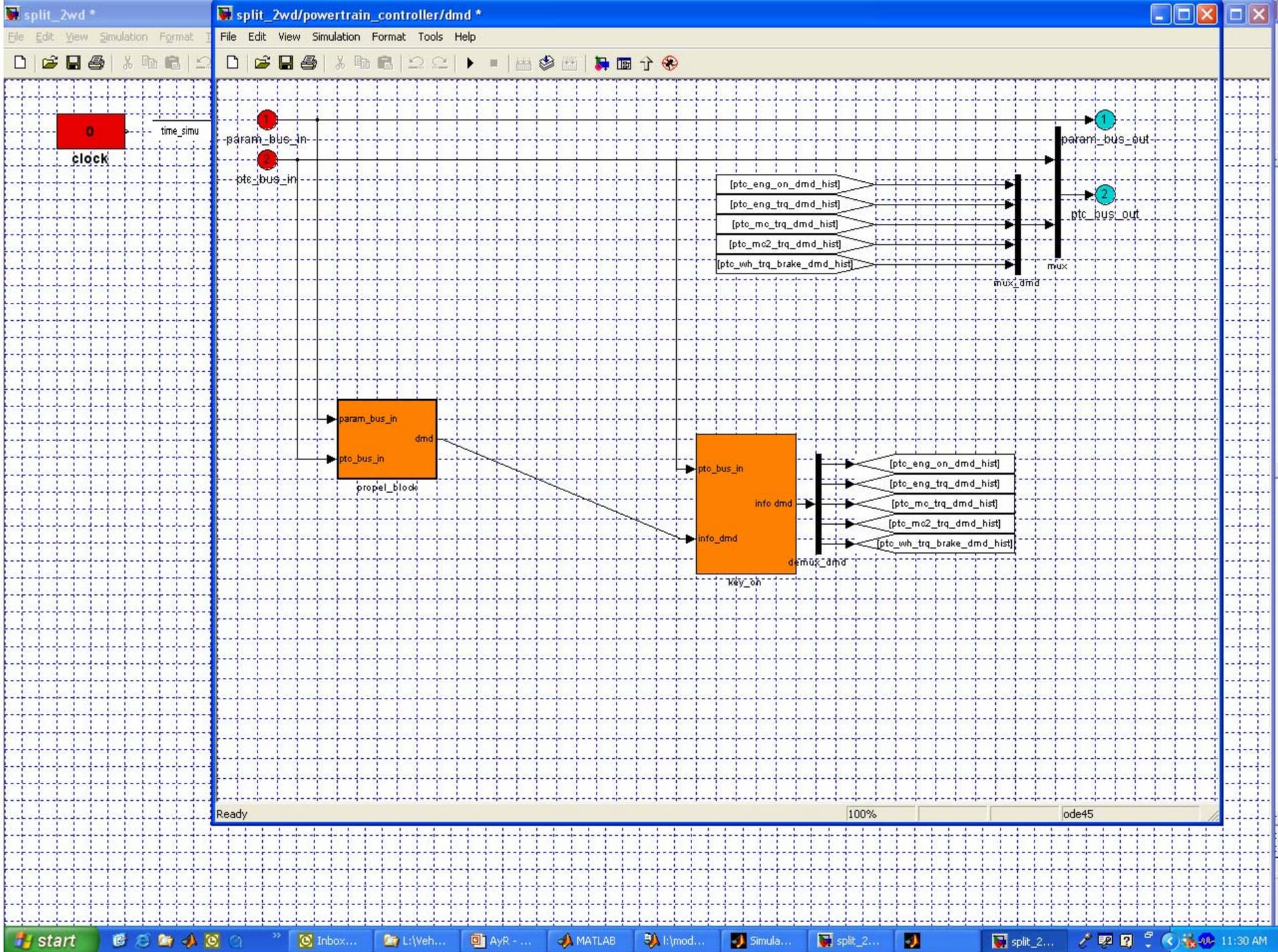
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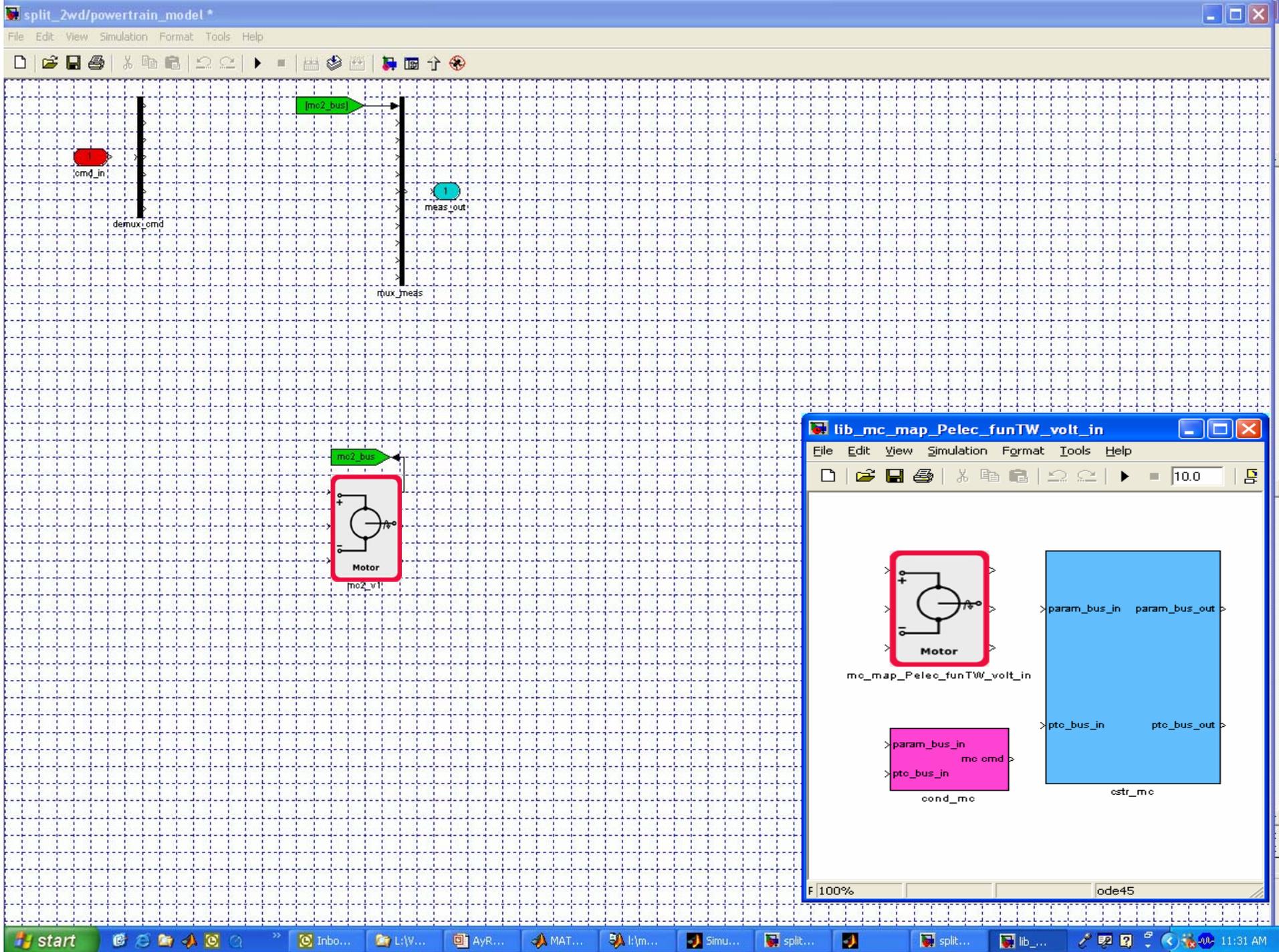


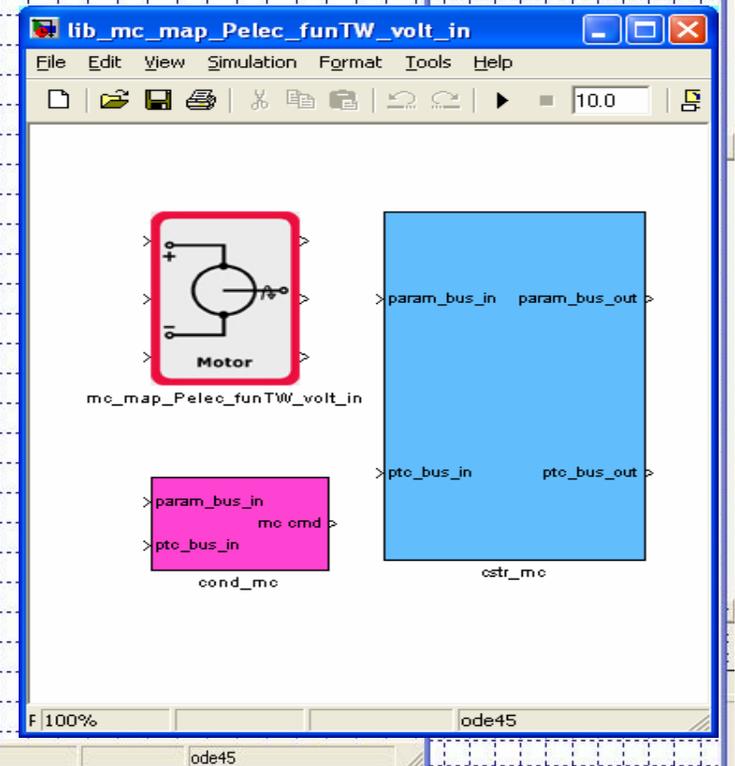
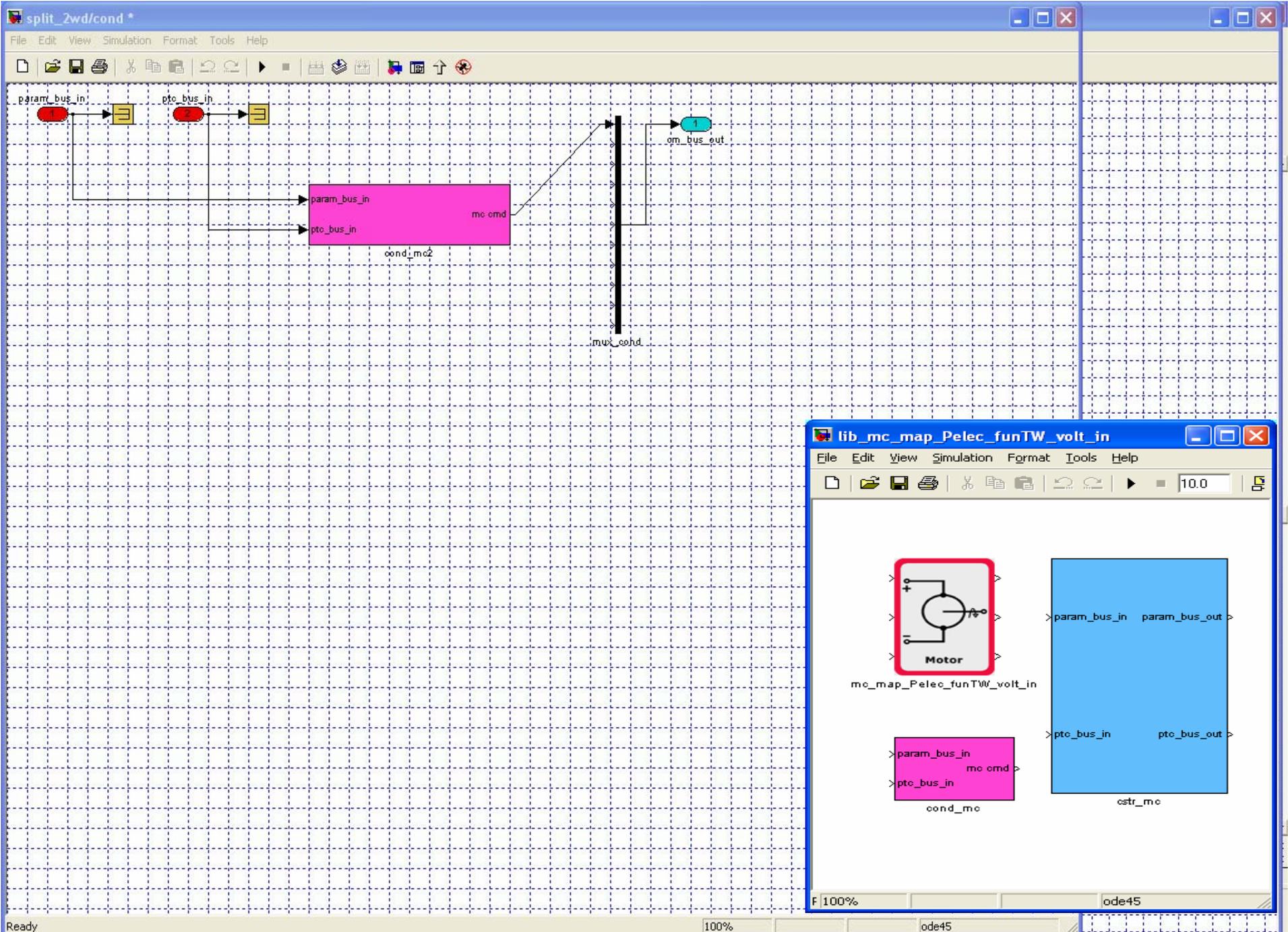


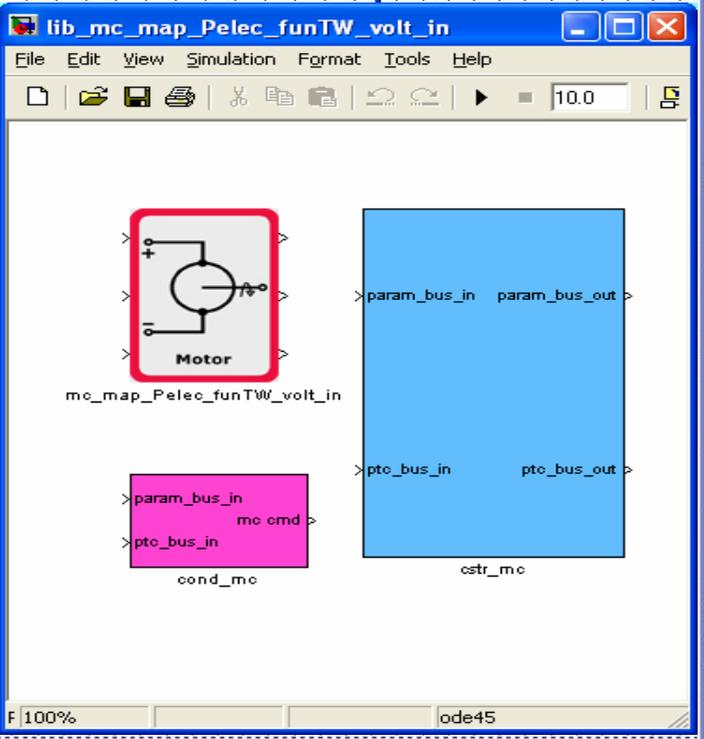
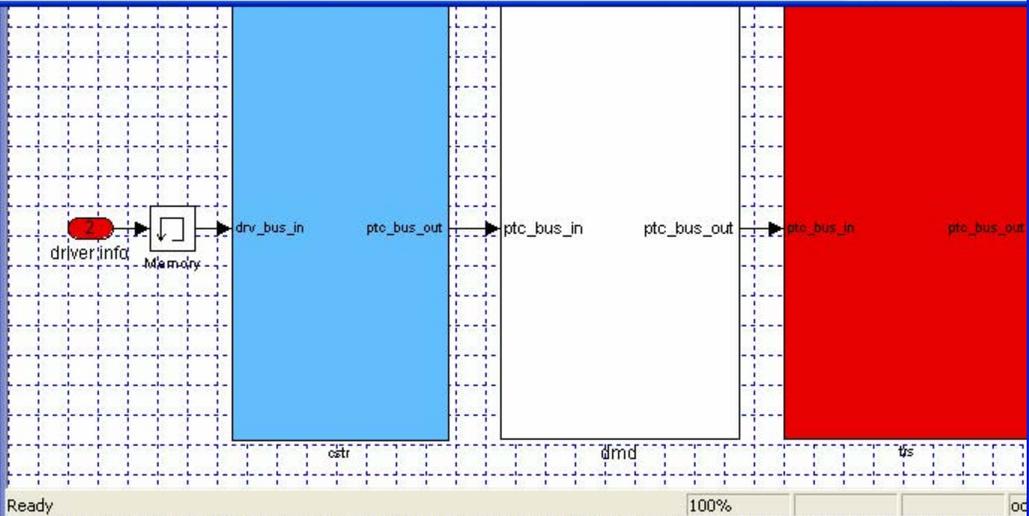
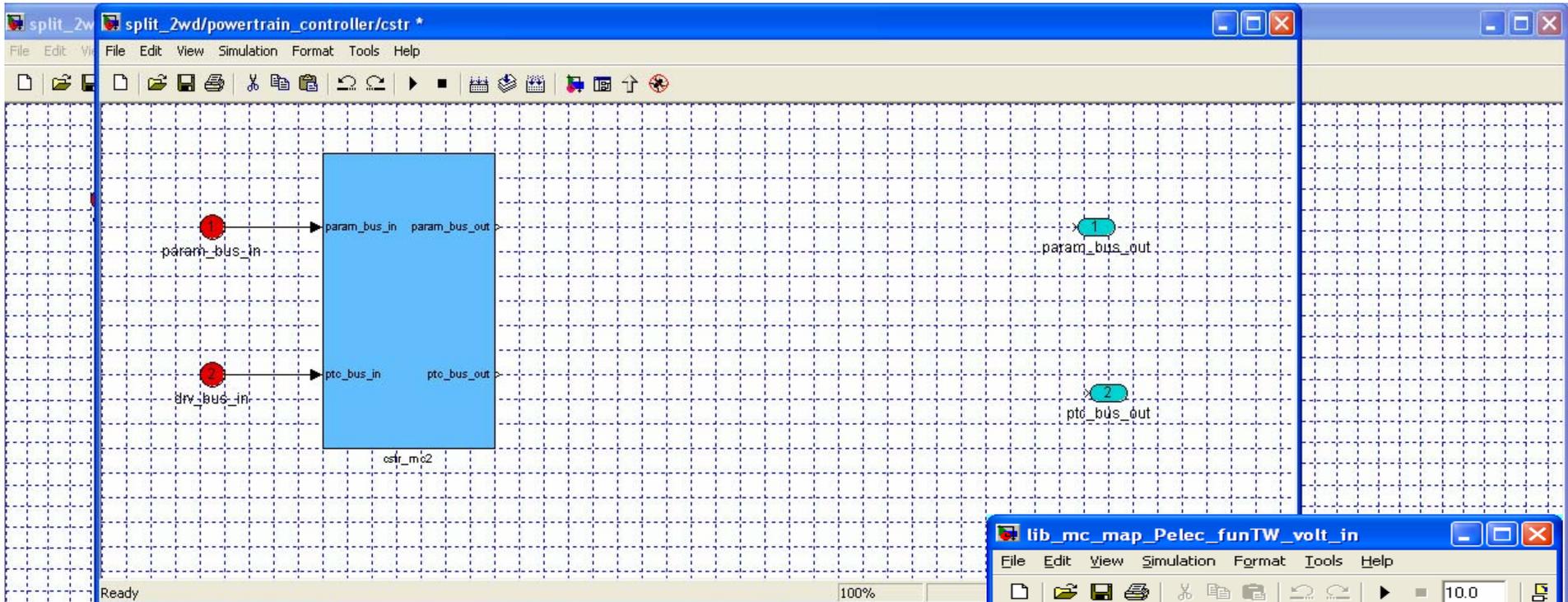


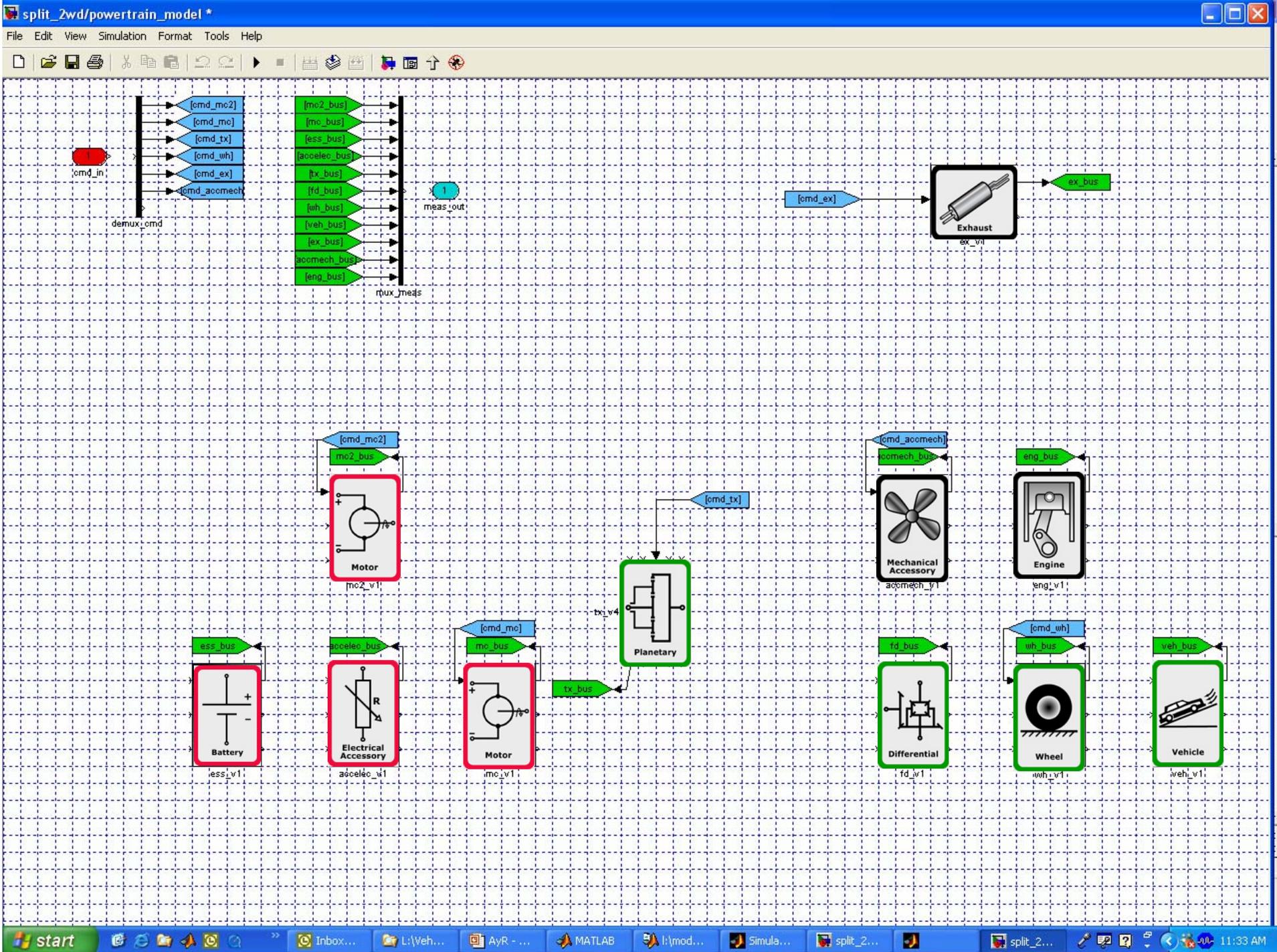


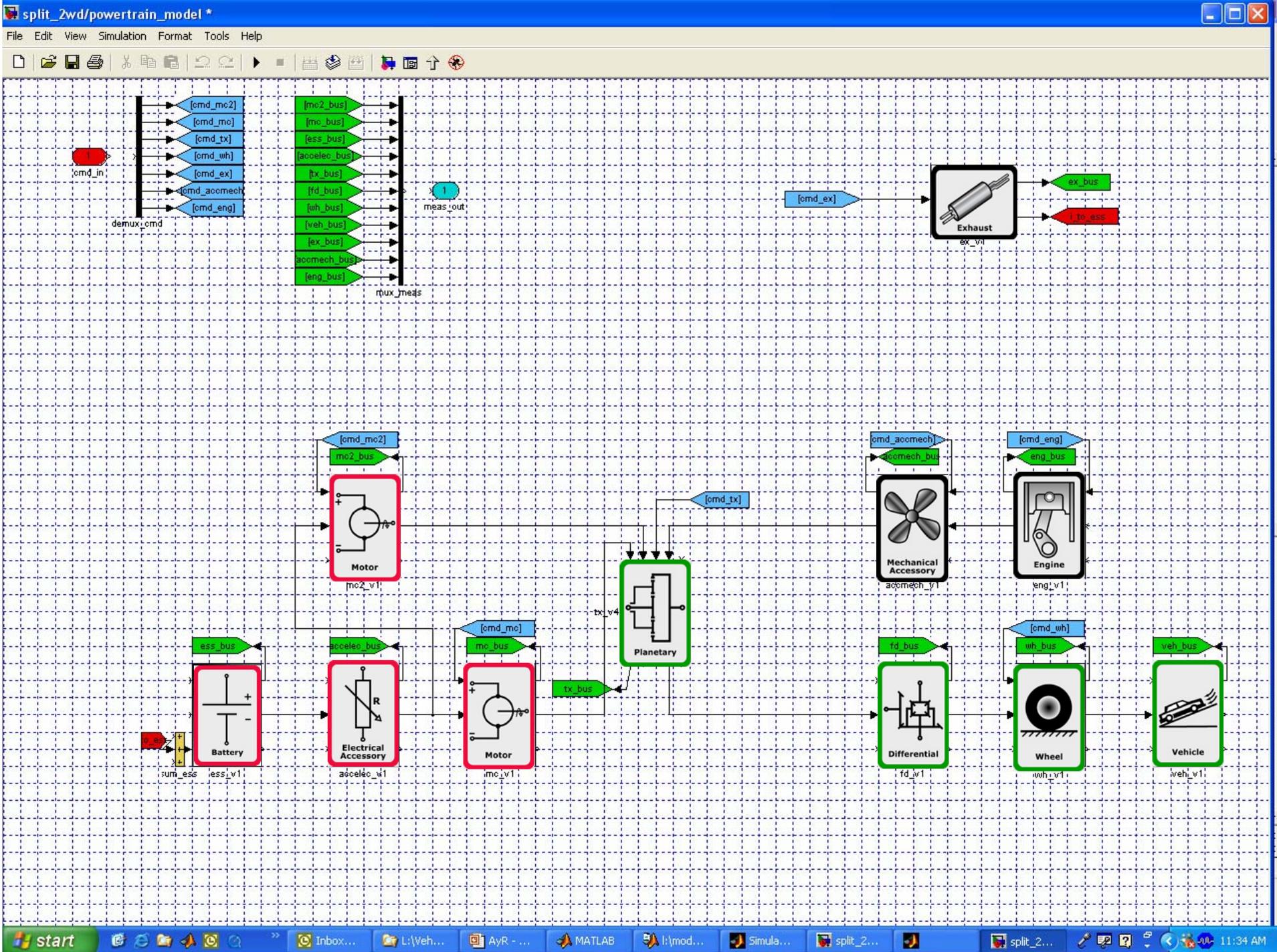


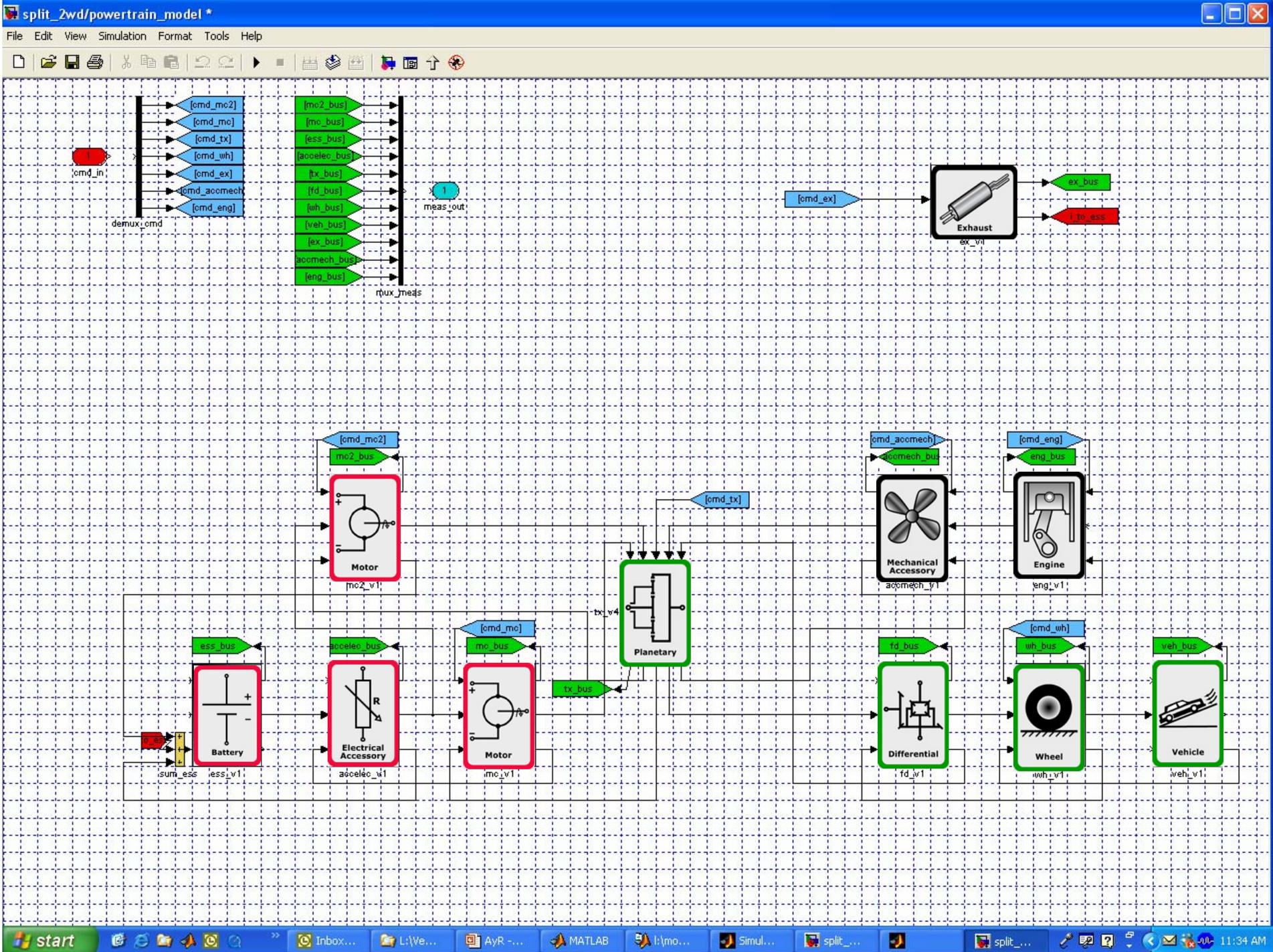


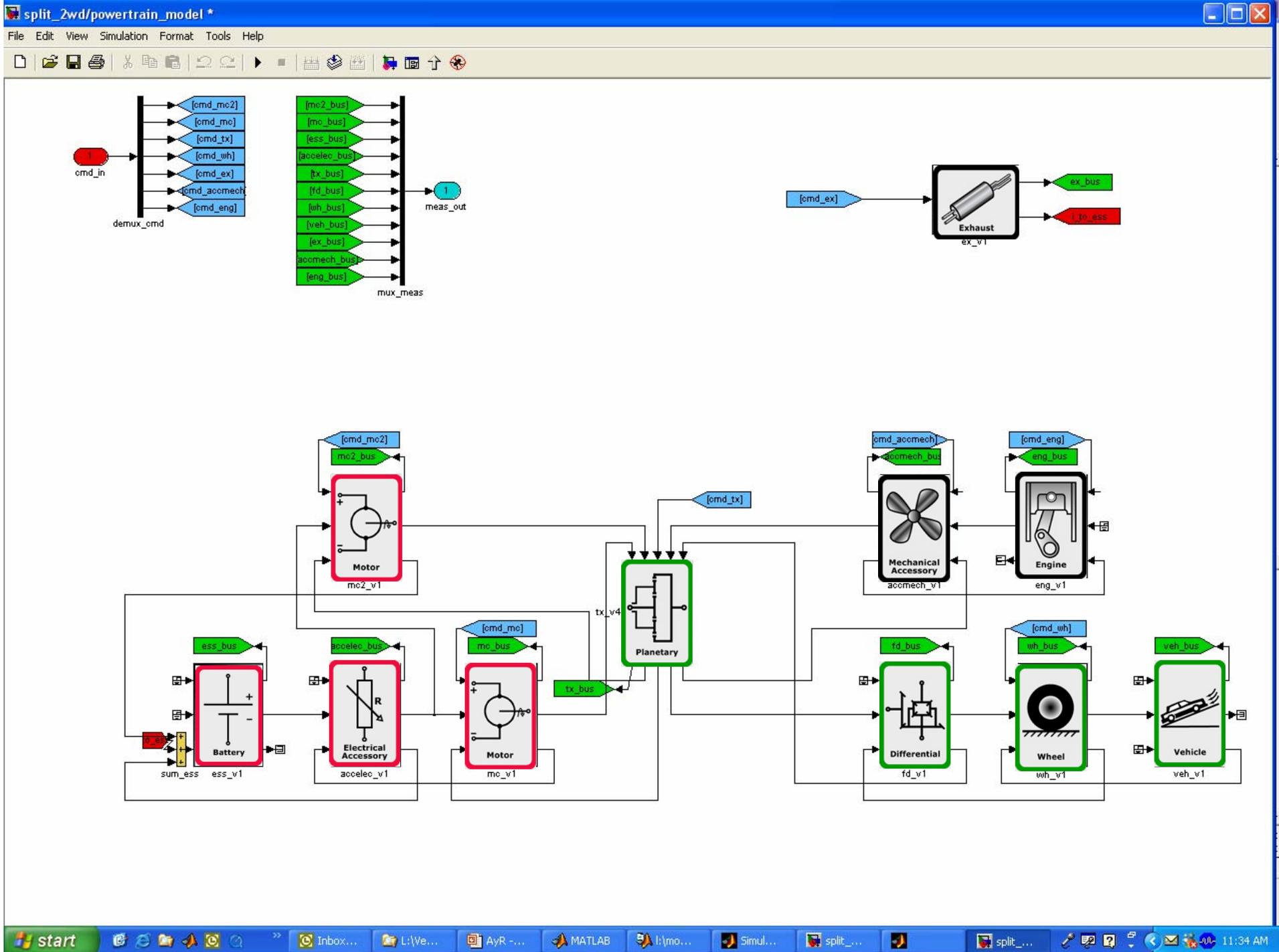


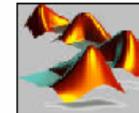
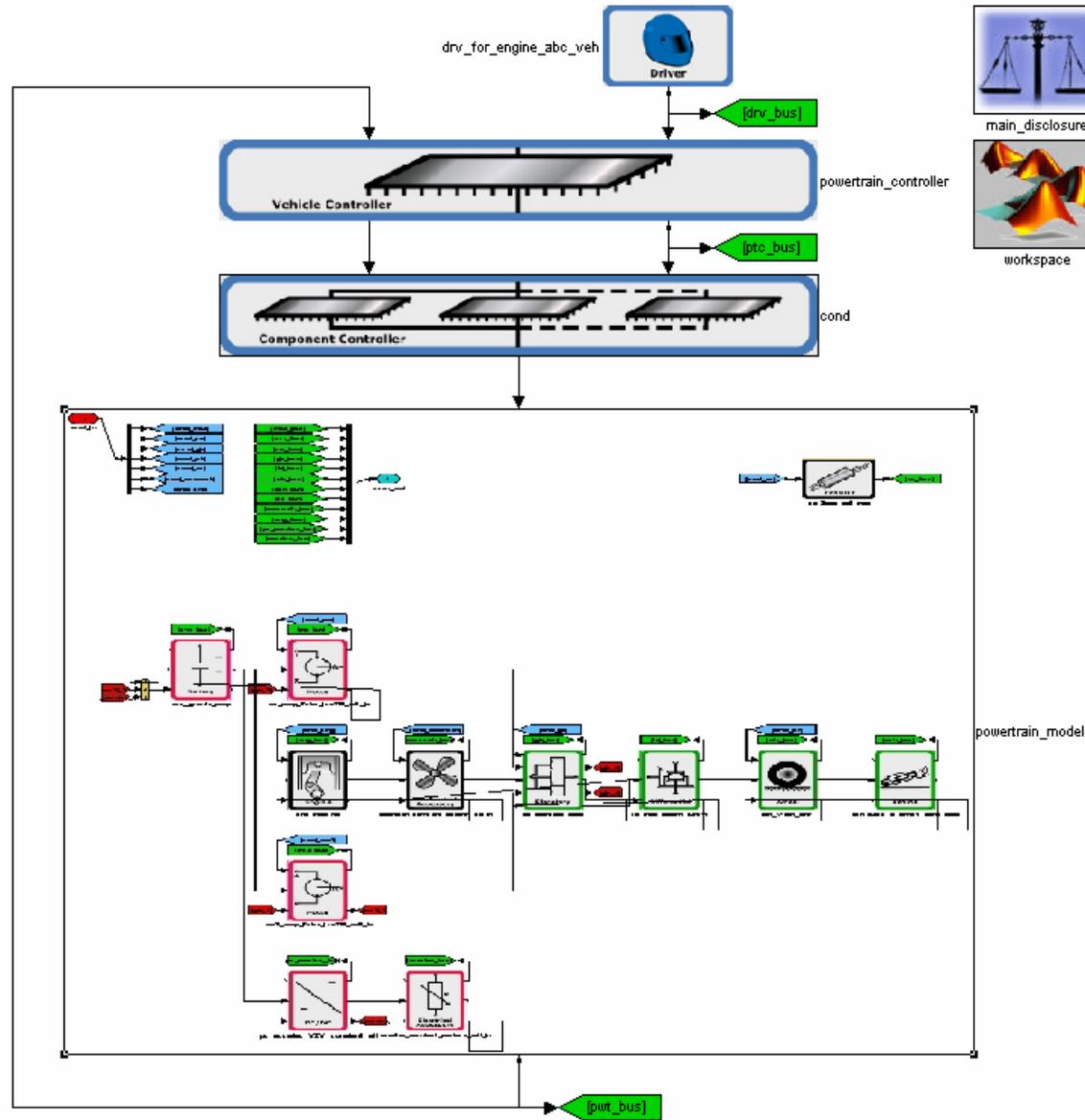
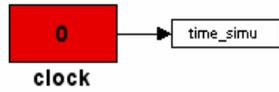












GREET Can Now Be Launched From PSAT

The screenshot displays the PSAT 6.1 - Powertrain System Analysis Toolkit interface. The top menu bar includes File, Simulation, Setup, PSAT-PRO, Units, Matlab, and Help. The main window is divided into several sections:

- Load Results:** Includes buttons for 'From Simulation', 'From Test', 'Compare Mode', and 'Open Report'.
- Select Results:** A list with 'Simulation # 1 (Load)' selected.
- Selected Result Set:** A table showing simulation details:

Name	Simulation # 1 (Load)
Configuration	fuelcell_2wd_p2
Strategy	build: p_fc_conso + b_fc
Simulation Setup	Combined Procedure (FTP+HMFET)
Data File	C:\psat_v62_beta1\users\shalbach\save_simu\fuelcell_2...
- Details:** A table showing performance metrics:

System Efficiency	22.577	%
Fuel Eco. Gas Equiv.	35.6283	mile/ga...
Elec. Consumption	0.77977	Wh/mile
SOC Init	70	%
SOC Final	68.601	%
Results Interval	0	3344
- Graphs:** A line graph showing 'drv_lin_spd_dmd (Simulation # 1) [mile/h]' over time. The x-axis represents time from 0 to 3344 seconds.
- Navigation:** Buttons for 'Assumptions', 'Main Results', 'Full Results', 'Data & Graphics', 'Energy Balance', and 'GREET'.
- GREET Section:**
 - Buttons for 'Get the latest version of GREET' and 'Select the location of the GREET file'.
 - Model Year: 2010
 - Share of H2 Production table:

Transportation Fuel Applica...	%
Central Plant	0
NG	0
Solar Energy	0
Nuclear (water cracking)	0
Electrolysis (HTGR)	0
Coal	0
Biomass	0
Refueling Station	100
NG	100
Electrolysis	0
EtOH	0
MeOH	0
 - Calculate >> button
 - Structure table:

Structure	Unit	Simulation # 1 (Load)	Description
- a.b Well_To_Pump			
Ec total_energy_consumption	Wh/mile	775.47	
Ec fossil_fuels_energy_consumption	Wh/mile	744.98	
Ec petroleum_energy_consumption	Wh/mile	16.61	
Ex co2_emission	g/mile	393.84	
Ex ch4_emission	g/mile	1.29	
Ex n2o_emission	g/mile	1.84 e-3	
Ex ghgs_emission	g/mile	424.11	
- a.b Pump_To_Wheels			
Ec total_energy_consumption	Wh/mile	1050.45	
Ec fossil_fuels_energy_consumption	Wh/mile	1050.45	
Ec petroleum_energy_consumption	Wh/mile	0	
Ex co2_emission	g/mile	0	
Ex ch4_emission	g/mile	0	
Ex n2o_emission	g/mile	0	
Ex ghgs_emission	g/mile	0	
- a.b Well_To_Wheels			
Ec total_energy_consumption	Wh/mile	1825.92	
Ec fossil_fuels_energy_consumption	Wh/mile	1705.43	

PHEV Battery Requirements

■ Objective:

Define battery requirements for short and long term for PHEVs

■ Collaboration with Energy Storage System TT

■ Progress:

- VL41M battery modeled
- Component models and control strategy defined
- Draft requirements provided for approval

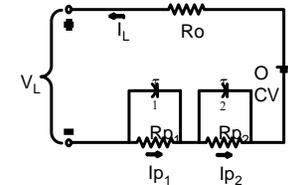
■ Future Directions:

- Using data from battery characterization and system evaluation (HIL), update the requirements

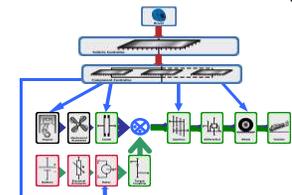
Battery Testing



Battery Modeling



Vehicle Modeling



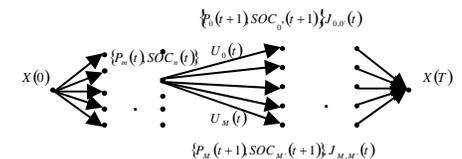
Batt HIL Validation



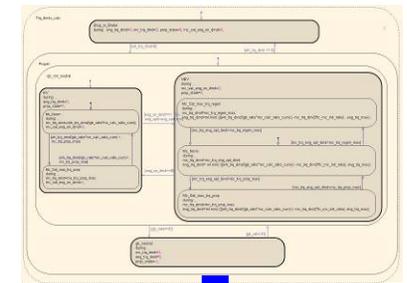
PHEV Control Strategy Development

- Objective:
 - Develop real-time control strategies for PHEVs
- Progress:
 - Global optimization algorithm used to view the “best” control for several driving cycles and distances
 - Preliminary controls developed in PSAT
- Future Directions
 - Develop control strategies focused on fuel economy
 - Evaluate the controls in MATT
 - Include thermal and emission impact

Global Optimization



Control Development (PSAT)



Control Evaluation in MATT



Students Used PSAT in Challenge X as a Design Tool



- cX teams have completed a powertrain selection process
- PSAT was used for:
 - Comparison of dozens of powertrain configurations and components to meet the competition goals.
 - Component sizing.
 - Development of specific control strategies for the powertrain architectures.
 - Control components in real time.



➔ Successful selection and development of powertrain within the time frame considered made possible through flexibility and reusability process

Examples of Collaborations

- Three year GM CRADA to further develop PSAT to become the reference for model organization within the automotive industry
- WFO with Hyundai (HEV control strategy)
- WFO with SK (Battery HIL)
- Redesign tools to follow PSAT architecture (e.g., ANL GREET, ORNL cost model)