

12 V Mild Hybrid – use case and battery requirements, EFB results

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Working team

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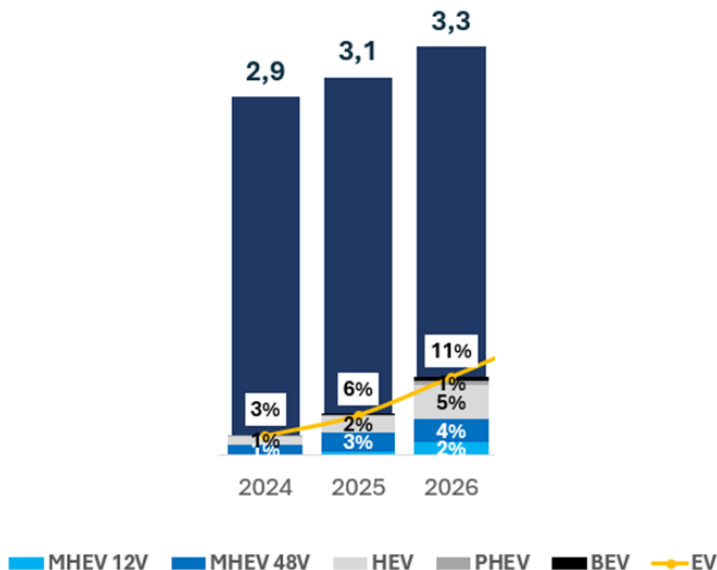
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ITEM
Laboratórios

Production Forecast [South America]

Evolution of Light-Duty Volume (pcs/month)

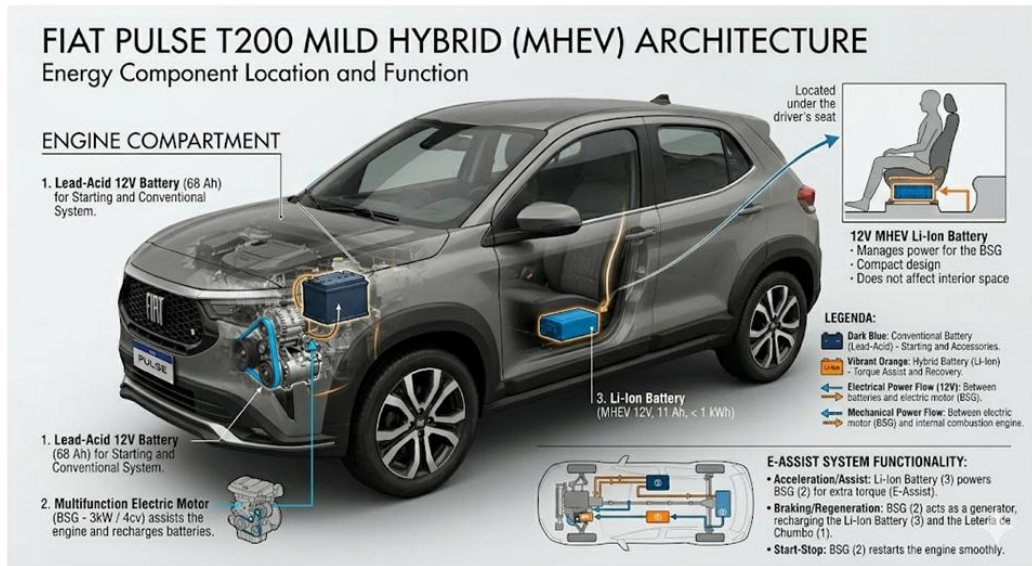


- Emerging markets must reduce fuel consumption and emissions without the cost and complexity of full hybrids or Evs
- In Brazil, national regulations require hybrid vehicles to include energy storage systems with nominal capacity $\geq 2\%$ of the energy generated during combustion
- The 12 V mild hybrid (mHEV) architecture offers:
 - 4–7% fuel consumption reduction, depending on control strategies
 - Minimal impact on existing powertrain architecture
 - Low technological risk and fast payback
- As a result, OEMs in these markets favor regulation-compliant, cost-effective electrification solutions

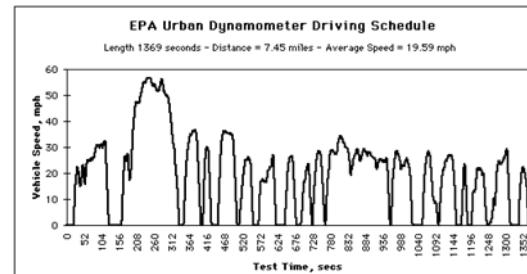
Objectives

- Instrument a 12 V mild-hybrid vehicle to capture key battery and powertrain signals
- Generate experimental data under representative urban and extra-urban driving conditions
- Develop a data-driven simulation algorithm based on measured vehicle behavior

Vehicle & Test cycle



- Fiat Pulse 2025 dual battery (68 Ah EFB + 11 Ah LIB), belt starter-generator (BSG)
- Urban Dynamometer Driving Schedule (UDDS)
- Data acquisition: Vector instrumentation

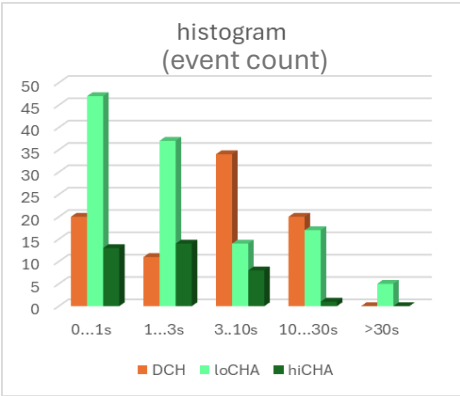


Operations mode Variable:

- Recup (hiCHA, +2): $U_{BSG} \geq 14.8\text{ v}$
- Normal (loCHA, +1): $I_{LIB} > 10$ and $U_{BSG} < 14.8\text{ V}$
- Boost (DCH, -1): discharge at $I_{LIB} < -10\text{V}$

Algorithm development steps:

- Filtering and preprocessing of measurement data
- Segmentation of operation into SOC phases(rising / falling / stable)
- Identification of energy balance per phase
- Extraction of control-relevant patterns

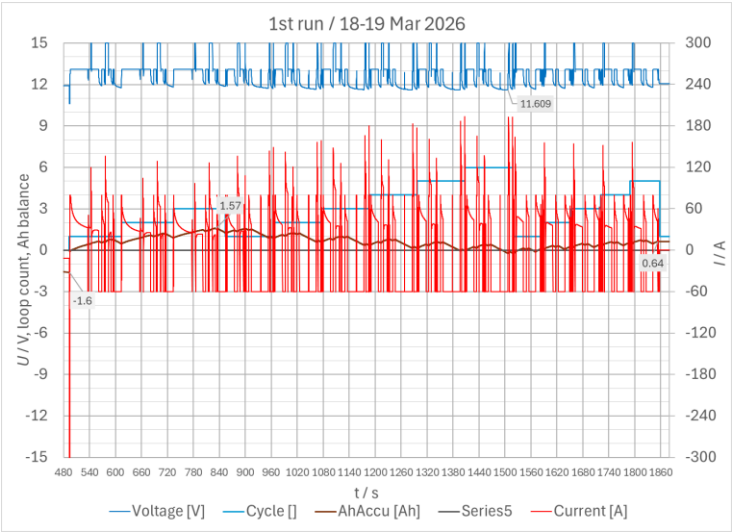


total steps per phase			
	DCH	loCHA	hiCHA
0...360s	15	23	7
360...1024s	43	65	24
1024...1363s	27	32	5
	85	120	36

total time per phase			
	DCH	loCHA	hiCHA
0...360s	91,5	240,4	28,2
360...1024s	371,7	240,9	50,5
1024...1363s	132,9	190,6	14,9
	596,0	671,9	93,6

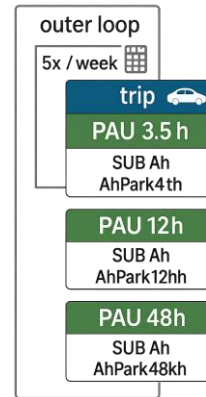
avg duration per phase			
	DCH	loCHA	hiCHA
0...360s	6,1	10,5	4,0
360...1024s	8,6	3,7	2,1
1024...1363s	4,9	6,0	3,0
	7,0	5,6	2,6

loops with durations in seconds					
loop1: 3* 120s		loop2: 6* 111s		loop3: 5* 67s	
loCHA	42.2	loCHA	1.8	loCHA	0.5
DCH	0.4	DCH	2.1	DCH	0.4
loCHA	6.0	loCHA	16.7	loCHA	1.8
hiCHA	1.9	DCH	6.4	DCH	2.1
loCHA	16.7	loCHA	0.5	loCHA	0.5
DCH	6.4	hiCHA	5.1	hiCHA	3.0
loCHA	6.0	loCHA	8.3	loCHA	16.7
DCH	2.1	DCH	2.1	DCH	6.4
loCHA	0.5	loCHA	1.8	loCHA	6.0
hiCHA	7.5	hiCHA	0.8	DCH	15.2
loCHA	6.5	loCHA	1.8	loCHA	10.8
DCH	4.2	DCH	6.4	DCH	0.4
loCHA	2.2	loCHA	6.0	loCHA	1.8
DCH	17.4	DCH	21.1	DCH	2.1
		loCHA	0.5		
		DCH	17.4		
		loCHA	1.8		
		hiCHA	1.9		
		loCHA	0.5		
		DCH	6.4		
		loCHA	0.5		
		hiCHA	0.6		



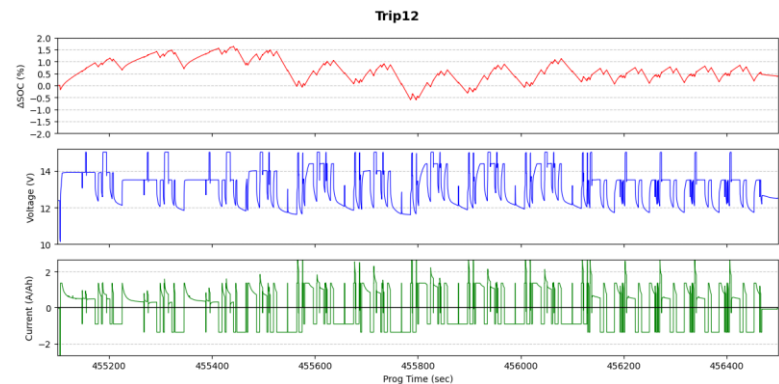
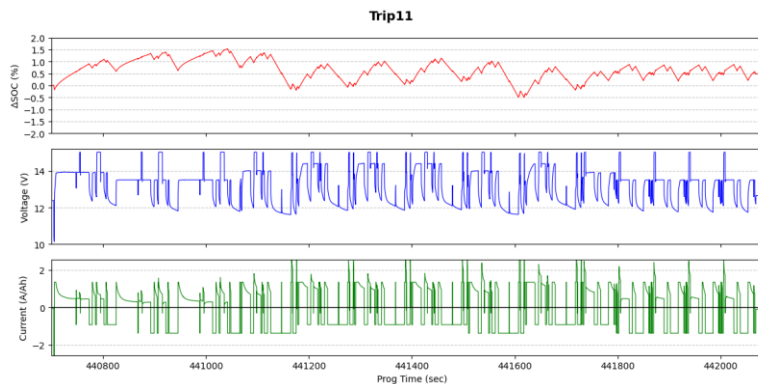
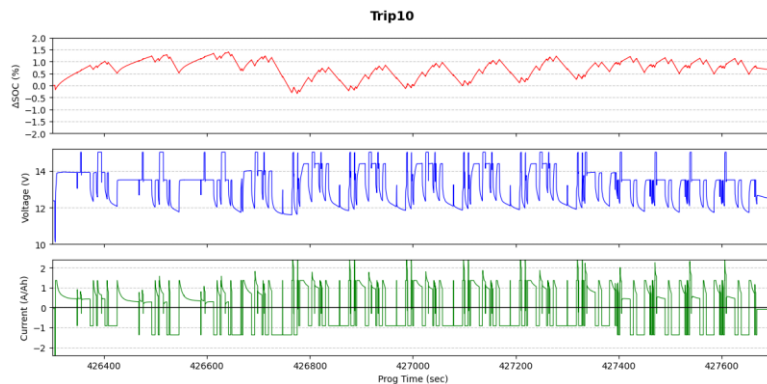
SOC control strategy:

- Definition of target SOC window based on real operation
 - Adaptation of control parameters:
 - Increase regeneration when SOC is low
- Increase assist limitation when SOC decreases
- Rule-based strategy to maintain positive energy balance over cycles



Trip Inner Loop 1				Trip Inner Loop 2				Trip Inner Loop 3			
	DCH	loCHA	hiCHA		DCH	loCHA	hiCHA		DCH	loCHA	hiCHA
SOC	[A]	[A]	[A]	SOC	[A]	[A]	[A]	SOC	[A]	[A]	[A]
OK = 0	2C	81	240	OK = 0	2C	81	240	OK = 0	2C	81	240
M1 = < -1%	1.5C	81	240	M1 = < -1%	1.5C	81	240	M1 = < -1%	1.5C	81	240
M2 = < -2%	1C	81	240	M2 = < -2%	1C	81	240	M2 = < -2%	1C	81	240
M3 = < -3%	0.5C	81	240	M3 = < -3%	0.5C	81	240	M3 = < -3%	0.5C	81	240
M4 = < -4%	-0,1	81	240	M4 = < -4%	-0,1	81	240	M4 = < -4%	-0,1	81	240

Trip Inner Loop 1				Trip Inner Loop 2				Trip Inner Loop 3			
	DCH	loCHA	hiCHA		DCH	loCHA	hiCHA		DCH	loCHA	hiCHA
SOC	[V]	[V]	[V]	SOC	[V]	[V]	[V]	SOC	[V]	[V]	[V]
OK = 0	9	13,1	15	OK = 0	9	13,6	15	OK = 0	9	13,1	15
M1 = < -1%	9	13,5	15	M1 = < -1%	9	14	15	M1 = < -1%	9	13,5	15
M2 = < -2%	9	13,9	15	M2 = < -2%	9	14,4	15	M2 = < -2%	9	13,9	15
M3 = < -3%	9	14,4	15	M3 = < -3%	9	14,8	15	M3 = < -3%	9	14,4	15
M4 = < -4%	9	15	15	M4 = < -4%	9	15	15	M4 = < -4%	9	15	15



Conclusion

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- A refresh standard EFB supplies more than ~80% of fuel-economy-related loads
- Energy balance and SoC control define system performance
- Charge acceptance is the main limiting factor
- Single-battery architectures are technically plausible

Next Steps:

- Refine SoC control strategies to better prioritize key operating modes
- Evaluate advanced lead-acid technologies and alternative battery chemistries
- Assess long-term performance and aging behavior under mHEV operation

