Scenario 3A — Steep Uphill Simulation

Metamorphic Relation Type: Composite (C)
Composite dynamic behavior under causal constraints

Description

This scenario evaluates the system’s behavior under a composite dynamic regime characterized by moderate constant speed and persistent positive acceleration.

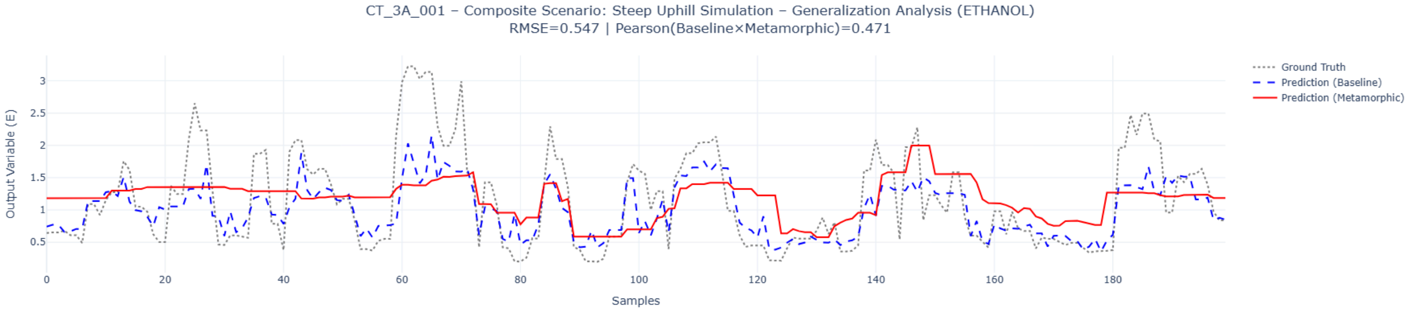
The test case simulates a steep uphill driving condition, in which the system is continuously subjected to increased load demand. Unlike isolated transformations applied in previous levels, this scenario combines multiple kinematic conditions into a coherent temporal pattern.

The objective is to observe whether the system produces a stable and causally consistent output under sustained positive acceleration, without execution interruption or erratic behavior.

Test Cases

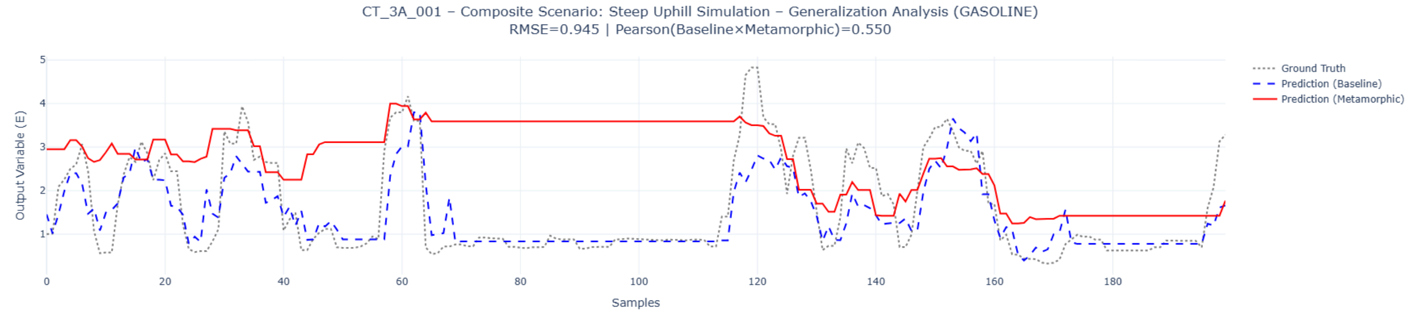
CT_3A_001 — Composite Scenario (Steep Uphill Simulation) — Ethanol

- **RMSE (Baseline × Metamorphic Prediction):** 0.5474
- **Pearson Correlation (Baseline × Metamorphic Prediction):** 0.471
- **Pearson Correlation (Ground Truth × Metamorphic Prediction):** 0.373



CT_3A_001 — Composite Scenario (Steep Uphill Simulation) — Gasoline

- **RMSE (Baseline × Metamorphic Prediction):** 0.9451
- **Pearson Correlation (Baseline × Metamorphic Prediction):** 0.550
- **Pearson Correlation (Ground Truth × Metamorphic Prediction):** 0.412



Scenario 3B — Downhill Inertia Simulation

Metamorphic Relation Type: Composite (C)
Composite dynamic behavior dominated by inertial effects

Description

This scenario evaluates the system’s behavior under a composite dynamic regime characterized by high speed and mild negative acceleration, representing a downhill driving condition dominated by inertia.

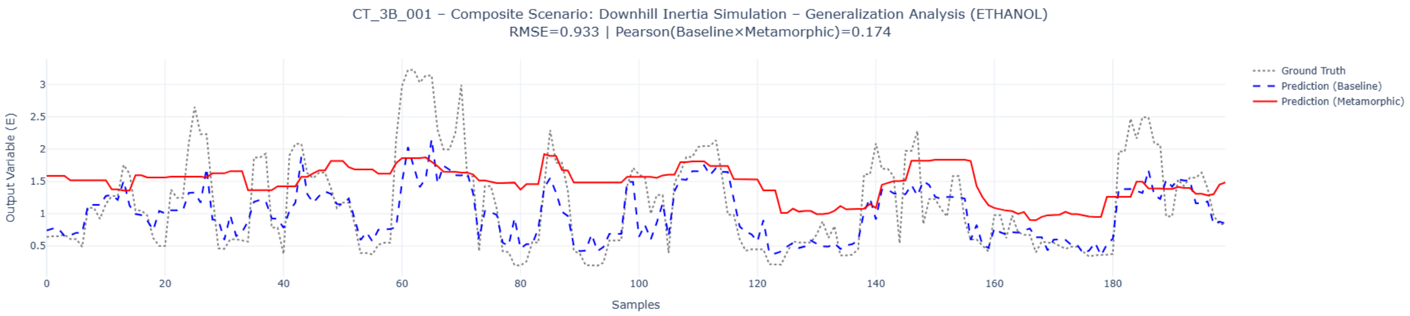
The test case models a situation in which the vehicle progressively loses speed without active braking, relying primarily on inertial and gravitational effects. This configuration combines kinematic variables in a semantically coherent manner, reflecting a realistic operational pattern.

The objective is to assess whether the system maintains causal consistency and execution stability when subjected to gradual deceleration driven by inertia rather than abrupt control actions.

Test Cases

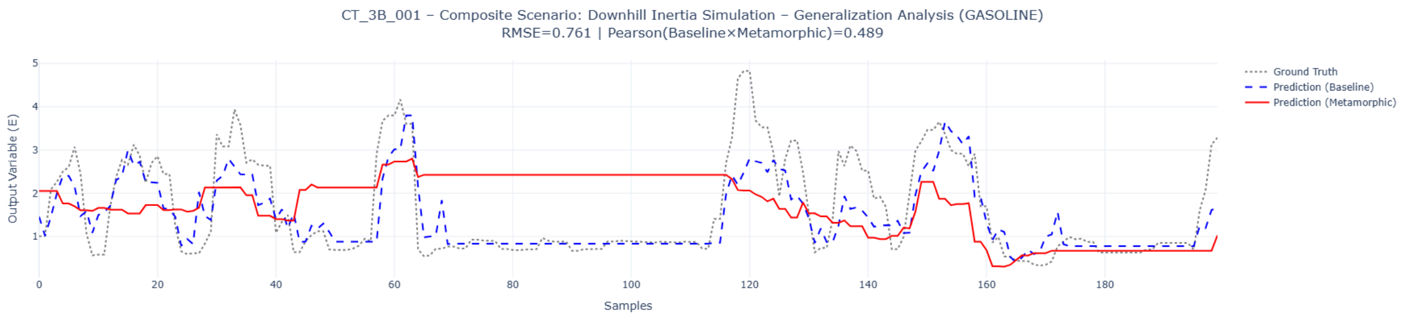
CT_3B_001 — Composite Scenario (Downhill Inertia Simulation) — Ethanol

- **RMSE (Baseline × Metamorphic Prediction):** 0.9333
- **Pearson Correlation (Baseline × Metamorphic Prediction):** 0.174
- **Pearson Correlation (Ground Truth × Metamorphic Prediction):** 0.140



CT_3B_001 — Composite Scenario (Downhill Inertia Simulation) — Gasoline

- **RMSE (Baseline × Metamorphic Prediction):** 0.7613
- **Pearson Correlation (Baseline × Metamorphic Prediction):** 0.489
- **Pearson Correlation (Ground Truth × Metamorphic Prediction):** 0.362



Scenario 3C — Hard Braking with Fuel Cut-Off

Metamorphic Relation Type: Composite (C)
Composite critical and transient dynamic behavior

Description

This scenario evaluates the system’s behavior during a critical transient event characterized by intense negative acceleration and rapid reduction of speed to zero, representing a hard braking condition with potential fuel cut-off.

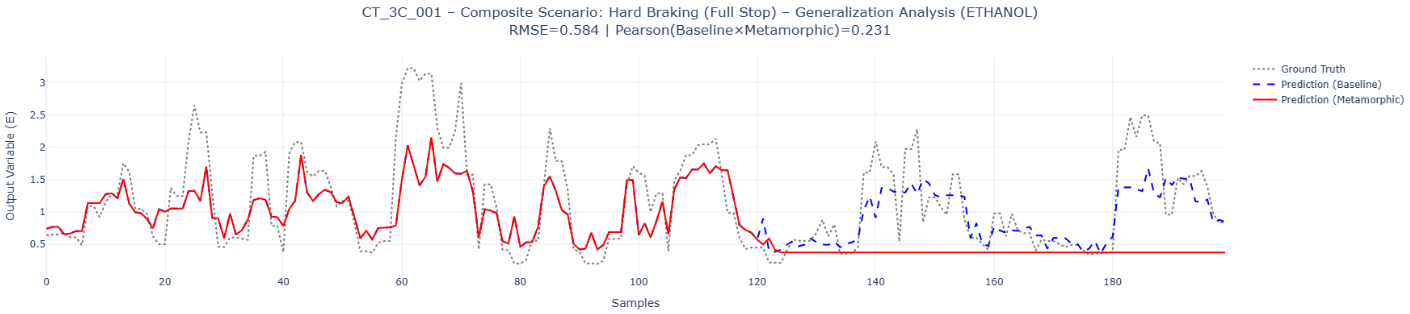
The test case models an abrupt deceleration pattern in which vehicle motion is rapidly interrupted. Such conditions impose strong dynamic discontinuities on the input signals and are expected to induce significant changes in the system output.

The objective is to assess whether the system preserves execution stability, causal coherence, and controlled output behavior when subjected to sudden braking events.

Test Cases

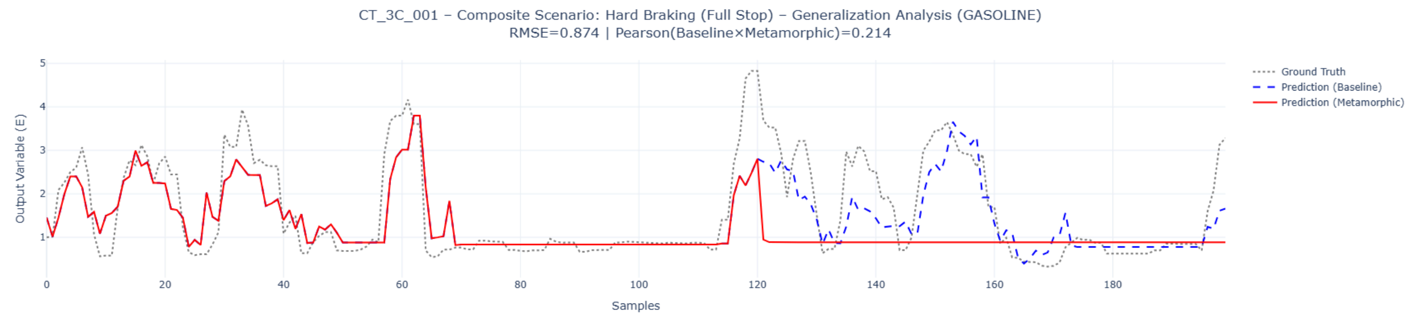
CT_3C_001 — Composite Scenario (Hard Braking / Fuel Cut-Off) — Ethanol

- **RMSE (Baseline × Metamorphic Prediction):** 0.5838
- **Pearson Correlation (Baseline × Metamorphic Prediction):** 0.231
- **Pearson Correlation (Ground Truth × Metamorphic Prediction):** 0.203



CT_3C_001 — Composite Scenario (Hard Braking / Fuel Cut-Off) — Gasoline

- **RMSE (Baseline × Metamorphic Prediction):** 0.8744
- **Pearson Correlation (Baseline × Metamorphic Prediction):** 0.214
- **Pearson Correlation (Ground Truth × Metamorphic Prediction):** 0.169



Scenario 3D — Constant Speed Cruise

Metamorphic Relation Type: Composite (C)
Steady-state dynamic equilibrium

Description

This scenario evaluates the system’s behavior under a steady-state operating condition characterized by constant speed and zero acceleration, representing stabilized cruising typically observed during highway driving.

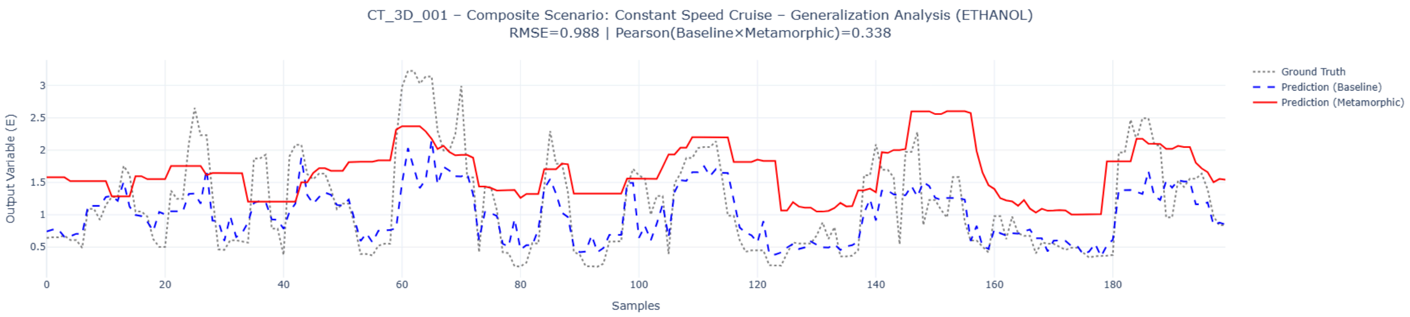
The test case models a dynamic equilibrium regime in which no transient events or external disturbances are present. Under such conditions, the system output is expected to exhibit stable and consistent behavior, reflecting the absence of acceleration-driven dynamics.

The objective is to assess whether the system maintains output stability, execution continuity, and coherent predictions when subjected to equilibrium input conditions.

Test Cases

CT_3D_001 — Composite Scenario (Constant Speed Cruise) — Ethanol

- **RMSE (Baseline × Metamorphic Prediction):** 0.9879
- **Pearson Correlation (Baseline × Metamorphic Prediction):** 0.338
- **Pearson Correlation (Ground Truth × Metamorphic Prediction):** 0.305



CT_3D_001 — Composite Scenario (Constant Speed Cruise) — Gasoline

- **RMSE (Baseline × Metamorphic Prediction):** 1.0376
- **Pearson Correlation (Baseline × Metamorphic Prediction):** 0.544
- **Pearson Correlation (Ground Truth × Metamorphic Prediction):** 0.409