

# ADAPTIVE HYBRID POWERTRAIN

## AHP

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*How to bring the "soul" back to the automobile in the age of electricity*  
An original concept for a new type of hybrid powertrain

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# 1. Introduction and core idea

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Electric vehicles have become faster, more efficient and more advanced than ever. Yet they have lost what shaped the emotional value of the automobile for decades - the mechanical sensation of a working engine. Sound, vibrations, throttle response, gear shifts - all gone.

Adaptive Hybrid Powertrain (AHP) is a powertrain in which the wheels are always driven by electric motors, while a gasoline engine is not mechanically connected to them - it spins a generator instead. The key innovation: the system uses software to control how hard the generator resists rotation, thereby creating real physical load on the engine. This load simultaneously generates electricity and produces the natural behavior, sound and sensations characteristic of a classic sports car.

*The sound is not synthesized through speakers - it occurs physically. But it is deliberately engineered: through exhaust design, generator load control and controller modes.*

## Concept priority

This concept was developed by the author and first documented in February 2024, when a complete description of the system was sent via email (Gmail) to Mate Rimac, CEO of Bugatti-Rimac. The letter remained unanswered, but the fact of sending is recorded in the email service.

In March 2026, Ferrari published patent US 2026/0077645 A1 "Series Hybrid Car and Corresponding Control Method", describing a series hybrid with two I6 engines mechanically decoupled from the wheels. Architecturally this confirms the relevance of the direction, but Ferrari's patent focuses on packaging (a deconstructed V12 from two inline sixes), not on controlling the generator load to create an emotional driving experience - which is the core idea of AHP.

## 2. System architecture

AHP is built as a series hybrid: the wheels are always driven by electric motors. The gasoline engine is not connected to the wheels directly - it spins a generator that produces electricity.

### Energy chain:

*ICE > Generator (MGU-G) > Power electronics > Battery > Electric motors > Wheels*

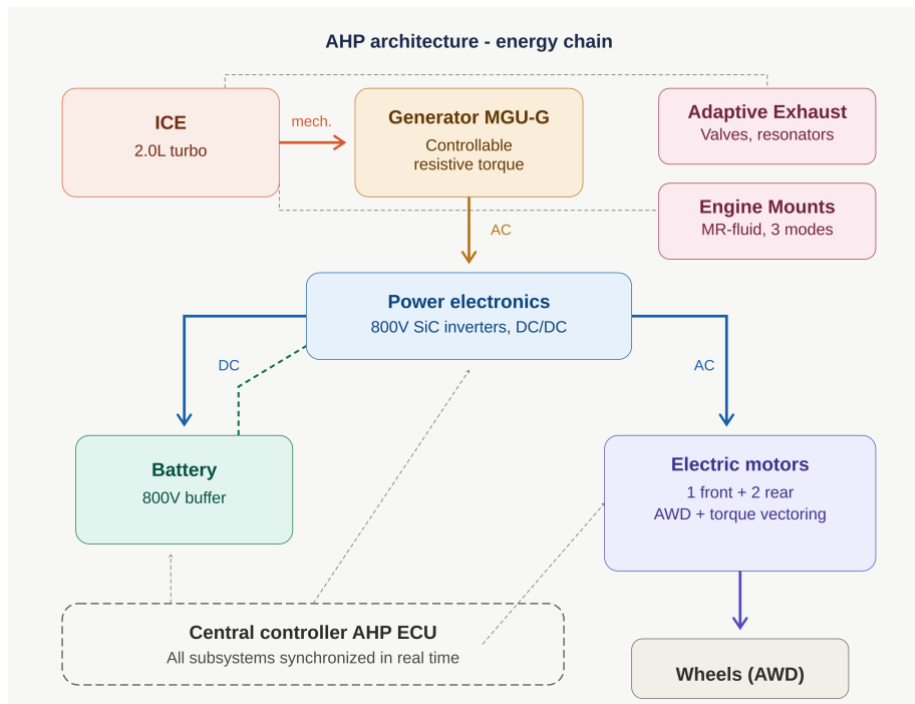


Fig. 1. Overall AHP architecture - energy chain and control links

### Key components

- **ICE** - turbocharged engine optimized for fast response and variable load (not for fixed RPM like in conventional hybrids).
- **Generator MGU-G** - an electric machine with software-controlled resistive torque. The key element: it doesn't just generate energy - it controls the physical state of the engine.
- **Battery (800V)** - energy buffer. Absorbs excess energy from the generator, delivers during peak loads, provides electric (EV) mode.
- **Electric motors (3 units)** - one on the front axle, two independent on the rear. All-wheel drive with torque vectoring.
- **Power electronics** - silicon carbide (SiC) inverters. Routes energy between the generator, battery and motors.
- **Adaptive exhaust** - controllable valves, resonators, unequal-length headers - acoustic shaping.
- **Adaptive engine mounts** - variable stiffness to transmit or isolate vibrations.
- **Central controller (AHP ECU)** - real-time synchronization of all subsystems.

The AHP architecture is not limited to a single mechanical layout. It can be implemented in 3-motor AWD or 4-motor AWD configurations and can use different ICE formats, from a compact inline-four to V6 or V8 engines. The present document illustrates a baseline compact configuration using a 2.0L turbocharged engine.

### 3. Core innovation: controllable generator load

*This is what makes AHP fundamentally different from all existing series hybrids.*

#### How it works

In all existing series hybrids (Nissan e-POWER, Chevrolet Volt Gen 1, BMW i3 REX) the generator performs a single function - converting mechanical energy into electrical energy. Its load is determined solely by the system's energy needs, and the goal is maximum silence and efficiency.

**AHP flips this logic.** The generator becomes a programmable load regulator for the engine. Resistance to the generator's rotation is determined by the current in its windings (Lenz's law): increasing the current increases resistance, and the engine works "under strain"; decreasing it lets the engine spin freely. The inverter controls this current virtually instantaneously.

**The key difference:** the load is tied not to the battery state, but to the driver's actions - throttle position, driving mode, current "virtual gear".

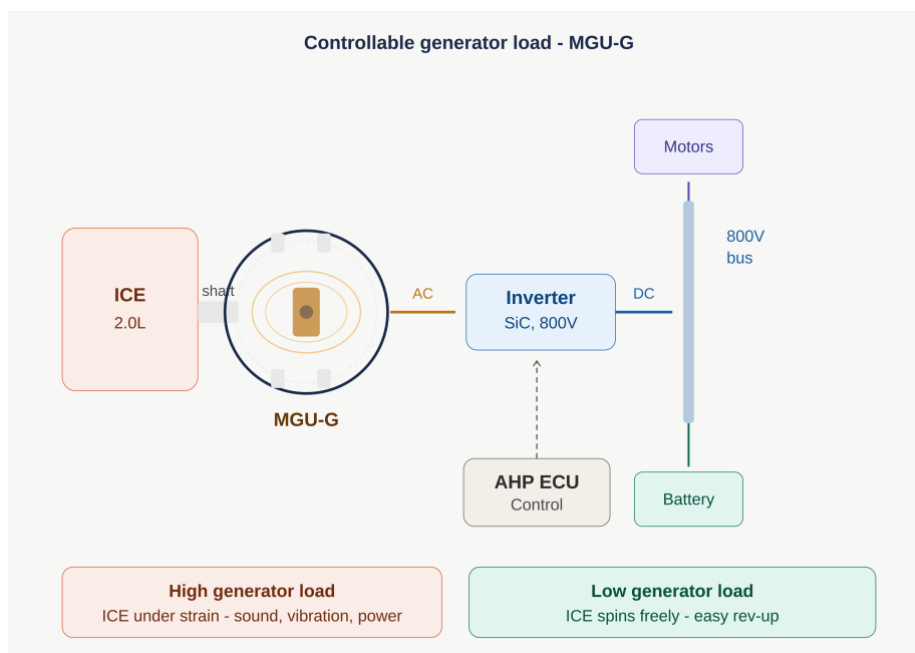


Fig. 2. Generator MGU-G - controllable resistive torque

#### What this achieves physically

When the engine is loaded, real physical processes occur: cylinder pressure rises, fuel delivery increases, exhaust energy grows. As a result - sound, vibration and the sensation of power emerge naturally. We control not just energy - we control the physical state of the engine.

Every newton-meter of generator resistance is not wasted - it is converted into electricity. Moreover, the increased excitation current induces a greater electromotive force (EMF) in the stator windings, making the conversion more efficient. The resulting energy goes to the battery or directly to the drive motors. Emotion is a byproduct of useful work.

## **Dual role of MGU-G: generator and motor**

The MGU-G is a motor-generator capable of operating in both directions. In its primary mode it loads the engine and generates electricity. But it can also switch to electric motor mode and spin the crankshaft - this is used for instant engine start, rev-matching during virtual "downshifts", and for creating exhaust pops on throttle lift-off (see Section 6 for details).

## 4. Acoustic engineering: deep sound from a small engine

The main acoustic challenge for AHP: a small four-cylinder turbocharged engine inherently sounds thin and unremarkable. The turbine further absorbs and smooths exhaust pulses. To achieve a deep, distinctive sound, a set of engineering solutions is employed.

### 4.1. Unequal-length exhaust headers

In the conventional approach, exhaust runner lengths from each cylinder to the collector are made equal - this optimizes scavenging and power. AHP takes the opposite approach: the runners are deliberately made unequal in length. This causes exhaust pulses from different cylinders to arrive at the collector at uneven intervals, creating an irregular, syncopated rhythm - the same "burbling" character familiar from Subaru Boxers and certain V8s.

**Why this is possible specifically in AHP:** in a conventional car, unequal-length headers worsen scavenging and reduce engine power. But in AHP the engine doesn't drive the wheels directly - it spins a generator. Therefore a small loss of thermal efficiency is perfectly acceptable for the sake of acoustic character.

### 4.2. Frequency-lowering resonators

A four-cylinder engine has a high fundamental firing frequency. To add depth and a "chesty" quality, two types of resonators are used.

- **Helmholtz resonators** - a chamber of specific volume with a calibrated neck. Tuned to a specific frequency, it amplifies low harmonics, effectively "thickening" the sound.
- **Quarter-wave resonators** - side branches of the exhaust tract tuned by length to the target frequency. They work like organ pipes: suppressing unwanted high frequencies and reinforcing low ones.

### 4.3. Firing order manipulation

Since the engine is decoupled from the wheels and there are no NVH (noise-vibration-harshness) constraints from the drivetrain, the ECU can experiment with firing intervals between cylinders. Uneven intervals (similar to big-bang firing order in MotoGP) produce a completely different acoustic character - from a low growl to a "staccato" crackle. This is yet another layer of programmable vehicle "character".

### 4.4. Acoustic pickup before the turbine hot side

The turbine hot side (turbine wheel) is the main "killer" of acoustics: it absorbs the energy of exhaust pulses and smooths the sound. However, diverting gases around the turbine is not an option - it would drop boost pressure precisely when power is needed. The task is not to redirect gases, but to capture the sound before the turbine wheel "eats" it.

**Solution:** sealed acoustic resonators (Helmholtz and quarter-wave) tapped into the exhaust manifold between the cylinder outlets and the turbine housing inlet - where pressure pulsations have not yet been smoothed by the turbine. The resonators pre-shape the pulsation spectrum at the turbine hot-side inlet so that after the inevitable smoothing by the turbine, more pronounced

low and mid-range harmonics are preserved in the exhaust tract. The resonators do not divert gas flow - they work on pressure impulses. The entire gas mass continues through the turbine; boost power is not lost.

#### 4.5. Second stage: resonators and valves after the turbine

After the turbine, the exhaust spectrum has been pre-shaped by the first stage but requires finishing. The second stage of resonators (also Helmholtz and quarter-wave) works with the residual spectrum - at lower pressures and energies, which allows for more precise, delicate tonal tuning.

Post-turbine resonators work in conjunction with electronic valves. Different valve + resonator combinations produce different sounds for each driving mode: full muffling in Comfort, partial in Sport, minimal in Track. This is two-stage acoustic processing: rough shaping before the turbine, fine finishing after.

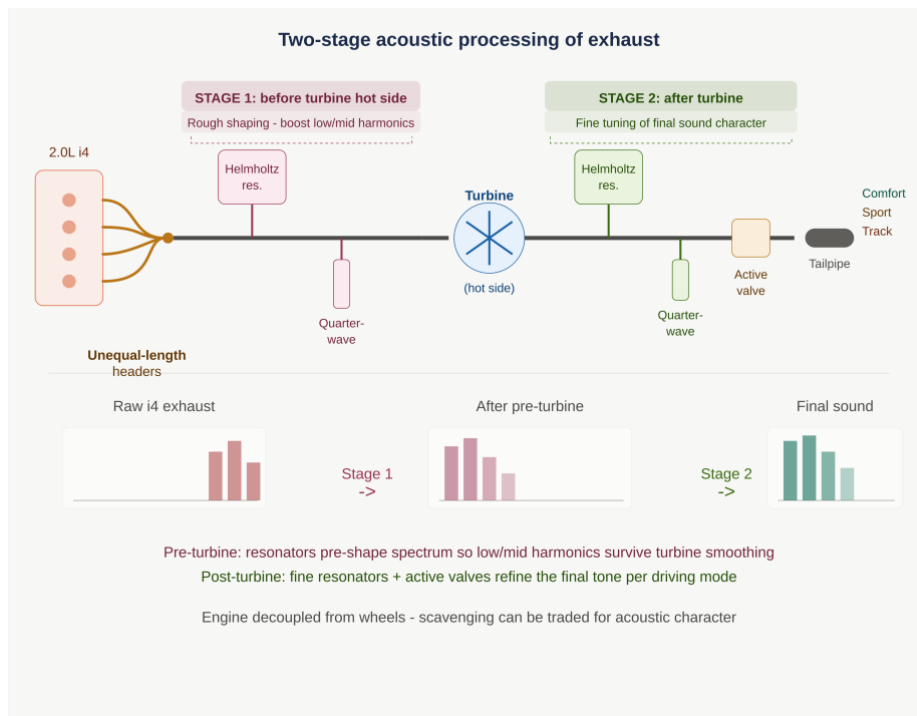


Fig. 3. Acoustic tract - engineering solutions for deep sound from a small engine

## 5. Simulated gear shifts (Virtual Gearbox)

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There is no mechanical gearbox in AHP. But the system reproduces its behavior through the coordinated work of two loops: the traction loop (electric motors on the wheels) and the acoustic loop (ICE + generator).

### What creates the physical sensation of shifting

The jolt during a gear shift is a sudden change of traction at the wheels. In AHP it is created by the drive electric motors:

**Step 1.** Brief traction interruption. The electric motors on the wheels abruptly reduce torque - the driver feels the characteristic "gap", as when a clutch disengages.

**Step 2.** Instant torque re-engagement. The electric motors sharply restore torque - an acceleration jolt occurs, as when engaging the next gear.

Electric motors can change torque virtually instantaneously - faster than any mechanical clutch. This allows precise tuning of the "shift" character: from smooth and gentle to sharp and aggressive.

### Acoustic accompaniment from the ICE

Simultaneously with the electric motors, the controller changes the generator load and ICE RPM:

- During the "traction break" - the generator load briefly drops, the engine unloads, RPM rises freely.
- During "re-engagement" - the generator load returns, RPM restructures to the new "gear", the sound changes.

The two loops work in sync: the driver simultaneously feels the jolt in the body (from the electric motors) and hears the shift with the ears (from the ICE). This creates a cohesive, convincing sensation of a mechanical gearbox.

Everything is software-configurable: number of "gears", shift points, jolt intensity, transition speed. Profiles can range from a smooth automatic to a sharp sequential.

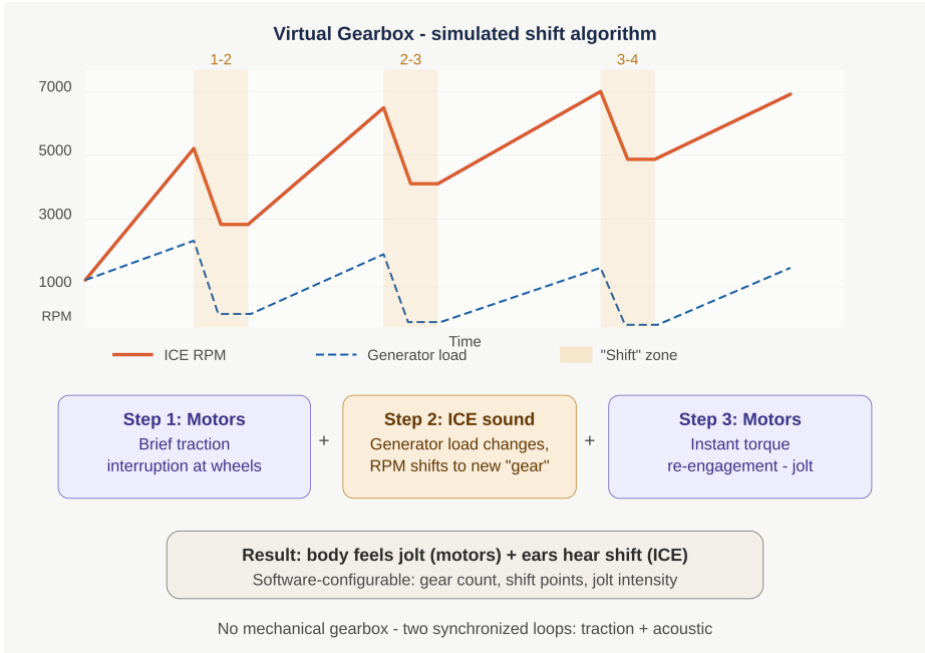


Fig. 4. Virtual Gearbox - RPM and load graph during simulated shifts

## 6. Active overrun: exhaust pops on throttle lift-off

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One of the most distinctive traits of aggressive sports cars is the popping and crackling from the exhaust on throttle lift-off. In conventional cars this is achieved through "crackle tunes" (retarded ignition, fuel injection into the exhaust), but control over the process is limited. In AHP this effect is implemented more elegantly and with full control.

### How it works

**Throttle lift-off.** The driver releases the pedal. In a conventional car, the engine continues to spin driven by the vehicle's inertia through the wheels - this is engine braking. In AHP the engine is not connected to the wheels, so on throttle lift-off nothing sustains its rotation.

**Generator switches to motor mode.** The MGU-G begins not braking but gently spinning the crankshaft, drawing a small amount of energy from the battery. It performs the same role that vehicle inertia through the wheels performs in a conventional car - keeping the engine spinning and maintaining airflow through the cylinders.

**ECU delivers fuel + retarded ignition.** Simultaneously the engine management unit injects fuel and sharply retards ignition timing (or cuts spark on some cylinders). The unburned air-fuel mixture enters the hot exhaust tract.

**Afterburn in the exhaust.** The fuel ignites in the hot manifold and turbine - pops, bangs and crackle result. Secondary air injection into the exhaust amplifies the effect.

### Why AHP does this better

In a conventional car, overrun behavior is dictated by vehicle inertia and the gear ratio - the engineer can tune it only within narrow limits. In AHP the motor-generator holds RPM at any desired level, regardless of vehicle speed. The intensity and duration of pops are set by the engineer during mode calibration - precisely and predictably.

### Rev-matching on "downshifts"

The same motor mode is used for rev-matching during virtual "downshifts" of the Virtual Gearbox. The generator briefly spins the engine up to the RPM of the new "gear" - creating a realistic blip, just like heel-toe on a manual.

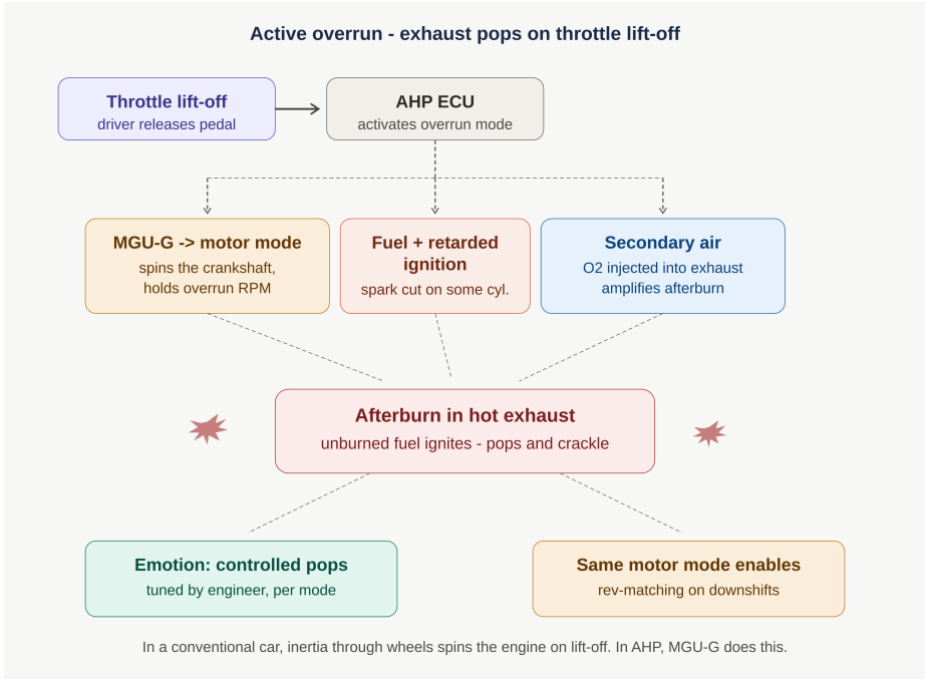


Fig. 5. Active overrun - exhaust pop mechanism on throttle lift-off

## 7. Controlled vibrations: adaptive engine mounts

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Modern cars strive to eliminate engine vibrations. AHP does the opposite - turning them into a controllable feedback channel.

The engine mounts use magnetorheological fluid - a material whose viscosity changes under a magnetic field. Increasing current in the mount coil makes the fluid stiff (vibrations are transmitted to the body). Decreasing it makes it soft (vibrations are isolated). Switching occurs in milliseconds.

In Comfort mode the driver doesn't feel the engine at all. In Sport - the engine is "felt" but doesn't annoy. In Track - maximum involvement: the car is physically "alive".

## 8. Software-defined driving modes

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The central controller synchronizes all subsystems and forms cohesive modes:

- **EV** - fully electric. ICE is off. Quiet urban driving.
- **Comfort** - mild hybrid. ICE runs unobtrusively, charging the battery. Vibrations isolated, exhaust muffled.
- **Sport** - active ICE operation. Sound, vibrations, simulated shifts. The engine is "felt".
- **Track** - maximum performance and involvement. Full power, aggressive sound, exhaust pops, stiff mounts.

Since the car's character is defined by software, OEMs can create different "personalities" on a single platform via OTA updates: from a comfortable GT to an aggressive sports car - through a firmware update.

## 9. Competitive comparison

### Hyundai Ioniq 5 N: simulation through speakers

The Hyundai Ioniq 5 N is currently the most advanced attempt to bring emotions back to an electric vehicle. The N e-Shift system simulates an 8-speed gearbox by limiting torque during "shifts". The N Active Sound+ system reproduces engine sounds through 10 speakers.

**The fundamental boundary:** with Hyundai, everything is synthesis. There is no real engine, no real load, no real sound. When blipping the throttle in "neutral", the revs on the tachometer rise but the motors are stationary - it's an animation. AHP creates all these sensations physically.

### Ferrari US 2026/0077645: architectural analog

Ferrari's patent describes a series hybrid with two I6 engines arranged in a V-shape and functioning as generators. Architecturally this is closest to AHP - the engines are decoupled from the wheels and spin generators. However, the patent focuses on physical packaging (a deconstructed V12), not on using controllable generator load as a tool for shaping the driver's emotional experience.

### Key differentiator of AHP

	Conventional hybrids	Hyundai N	AHP
<b>Generator</b>	Energy production	No ICE	ICE behavior control
<b>Sound</b>	Suppressed	Speakers	Physical, engineered
<b>Gear shifts</b>	None	Torque limiting	Generator load + motors
<b>Exhaust pops</b>	None	Speaker sounds	Real afterburn
<b>Vibrations</b>	Suppressed	None	Controllable (MR-fluid)

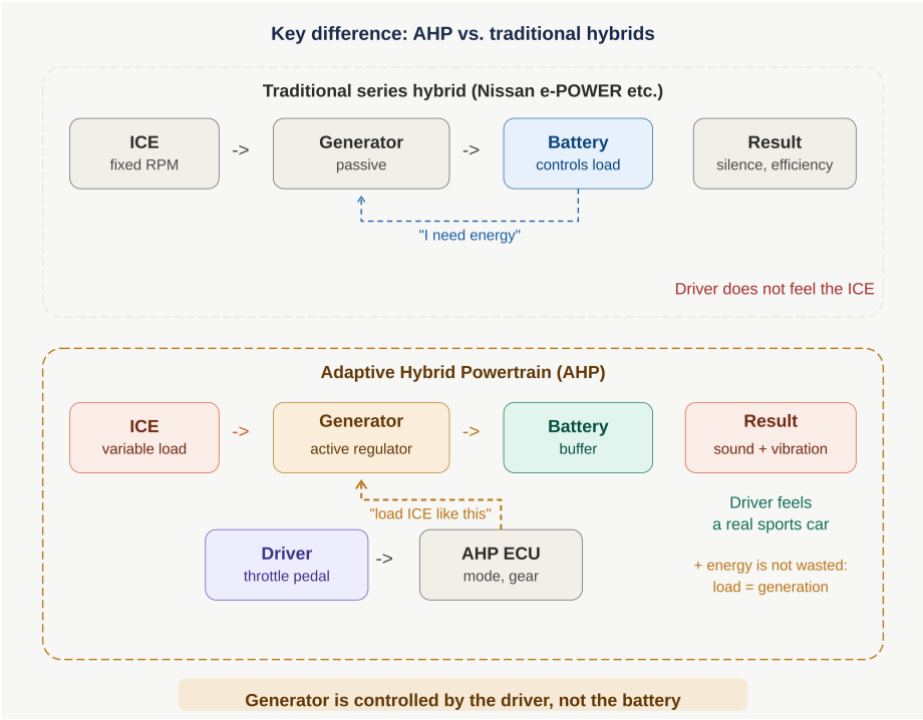


Fig. 6. The fundamental difference: in AHP the generator is controlled by the driver, not the battery

## 10. Conclusion

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Adaptive Hybrid Powertrain is not an improvement on existing hybrids. It is a new category: a car with an electric architecture and mechanically authentic sensations, controlled by software.

In this architecture the engine no longer drives the wheels - but becomes a source of both energy and emotion. The generator ceases to be a passive element - and becomes a tool for controlling the physics of the car. The exhaust system transforms from a muffler into a musical instrument. And the controller gains the ability to create an unlimited number of vehicle "characters" through software.

*The result: an electric vehicle that feels like a real sports car.*

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