A Systematic Review of Technologies, Control Methods, and Optimization for Extended-Range Electric Vehicles

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Review

A Systematic Review of Technologies, Control Methods, and Optimization for Extended-Range Electric Vehicles

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Abstract: For smart cities using clean energy, optimal energy management has made the development of electric vehicles more popular. However, the fear of range anxiety—that a vehicle has insufficient range to reach its destination—is slowing down the adoption of EVs. The integration of an auxiliary power unit (APU) can extend the range of a vehicle, making them more attractive to consumers. The increased interest in optimizing electric vehicles is generating research around range extenders. These days, many systems and configurations of extended-range electric vehicles (EREVs) have been proposed to recover energy. However, it is necessary to summarize all those efforts made by researchers and industry to find the optimal solution regarding range extenders. This paper analyzes the most relevant technologies that recover energy, the current topologies and configurations of EREVs, and the state-of-the-art in control methods used to manage energy. The analysis presented mainly focuses on finding maximum fuel economy, reducing emissions, minimizing the system's costs, and providing optimal driving performance. Our summary and evaluation of range extenders for electric vehicles seeks to guide researchers and automakers to generate new topologies and configurations for EVs with optimized range, improved functionality, and low emissions.

Keywords: extended range electric vehicle; technologies; optimization methods; EREV key components; level optimization

1. Introduction

Extended-range electric vehicles (EREVs), commonly known as series hybrid electric vehicles (Series-HEV), have better autonomy than electric vehicles (EV) without range extenders (REs). EREVs can go from one city to another or make long journeys in general. In recent years, EREVs have attracted considerable attention because of the necessity to improve autonomy using new and different technologies to generate extra energy for EVs. Today, fossil fuels meet the needs of the transportation sector to a significant extent, but bring on various adverse effects, such as air pollution, noise, and global warming. Compared to internal combustion engine vehicles (ICEVs), EREVs reduce emissions and are considered a favorable alternative [1,2]. EREVs, compared with EV, not only have the advantage of "zero fuel consumption and zero emissions"; they also effectively solve the problem of having an inadequate driving range due to power storage limitations in batteries [3]. This paper presents a systematic review on the subject of EREVs. First, an explanation of all the technologies used to extend the ranges of electric vehicles is presented and compared, considering the characteristics of each technology. The next stage reviews all the possible topologies for an EREV, analyzing the components and their interactions. The different control methods and their applications are also analyzed. The last part the analysis of how an EREV can be optimized. All the information is organized and presented in graphs and tables. As a contribution of our own, we propose a method for selecting the components of an EREV and designing its architecture based on the final application and use.

2. Extended Range Electric Vehicle Technology

A range extender (RE) is a small electricity generator (APU) which operates when needed as a solution to increase autonomy in EVs. The main components of the RE are the generator and internal or external combustion engine; the internal or external combustion engine is coupled to the generator in a series configuration. The primary function of the RE for an EV is to extend the vehicle's mileage. Operation of the range extender is initiated if the SOC (state of charge) of the EVs battery drops below a specified level. In this situation, the engine provides electricity by recharging the battery or directly driving the EV during travel and continues the vehicle's operation [4]. The difference in a plug-in hybrid electric vehicle (PHEV) is that the electric motor always propels the wheels. The engine acts as a generator to recharge the vehicle's battery when it depletes or as it propels the vehicle [5]. A series configuration is used as the main system, which is considered an APU. The system is connected to several subsystems, such as the generator, battery, electronic management system, and electric motor. The electric motor converts electrical energy from the battery to mechanical power. It propels the wheels while the APU generates electric energy to recharge the battery. Finally, the electronic management system controls all the systems for optimal functioning. The EREV has two operation modes: pure electric vehicle and extended-range mode. If the distance is short, the vehicle operates in pure electric vehicle mode without the RE. If the distance is long, the vehicle operates in extended-range electric vehicle mode.

The RE is off as long as there is sufficient energy in the battery for purely electric driving, and activated whenever the SOC drops below a certain level. The RE works until the desired SOC is achieved. The battery power manager gives this function. Figure 1 shows an EREV and energy flow configuration: (a) charge sustaining period and (b) depletion period. There are many technical and social challenges ahead for EVs coming up against the conventional ICEVs. Range anxiety is the most challenging problem facing EV drivers due to their shorter driving ranges compared to ICEVs. Range anxiety stems from the limited energy density in the current batteries (0.565 MJ/kg for Li-ion battery), which is very low as compared to fossil fuel (43.48 MJ/kg) [6].

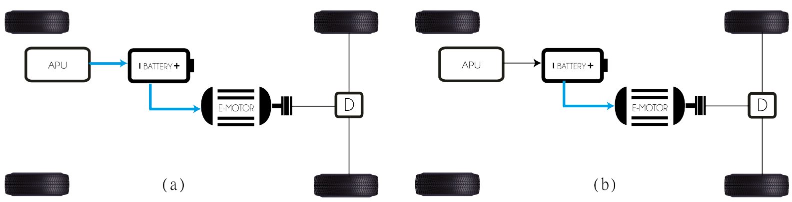

Figure 1. Configuration of an EREV and energy flow: (**a**) charge sustaining period; (**b**) depleting period.

2.1. Technological Classification of EREV

The electric propulsion system is the heart of an EREV. It consists of the motor drive, a transmission (optional) device, and wheels. There are three kinds of electric motors: direct or alternating current and in-wheel motors (also called wheel motors). The primary requirements of the EREV motor are summarized as follows:

1. High instant power and high power density.
2. High torque at low speeds for starting and climbing, and high power at high speeds for cruising.

3. An extensive speed range including constant-torque and constant-power regions. In this case, the APU, when it is on, needs to operate in the same regions.
4. Fast torque response.
5. High efficiency over a large speed and torque ranges.
6. High reliability and robustness for various vehicle operating conditions.
7. Reasonable cost.

2.1.1. Internal Combustion Engine Extended Range (ICE-ER)

The range extender comprises a fuel tank, an internal combustion engine, and a permanent magnet synchronous generator [3,6–34], as shown in Figure 2. The structure is mechanically decoupled between the RE and the wheels of the EV. This configuration leads to a strong point whereby the output characteristics of the RE are not related to the vehicle's traction performance, and the output power only needs to meet the driving requirements. Therefore, one of the main objectives is to keep the RE operating in the high-efficiency region. The engine and the generator should be matched to achieve this common operating region [8]. As another solution, several studies have focused on energy harvesting using other types of fuels, such as natural gas [35] or diesel [36,37], to reduce pollution levels.

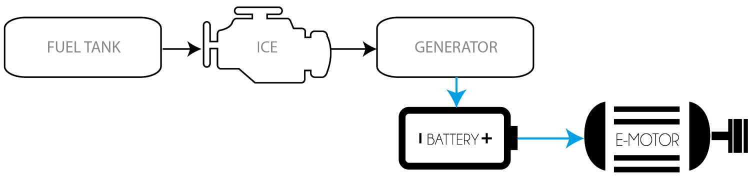

Figure 2. A diagram of the configuration of ICE-ER.

2.1.2. Regenerative Shock Absorber Extended Range (RSA-ER)

The shock absorber is a crucial component of the vehicle suspension and is combined with the suspension spring to filter vibrations when driving on rough roads. Typically, energy from vibrational sources is dissipated through hydraulic friction and heat via shock absorbers [38]. Currently, there are three categories for RSAs. The first type directly uses an electromagnetic method to generate electric power. The schemes of operation can be linear or rotary [39]. A linear electromagnetic RSA converts the kinetic energy of vertical oscillations into electricity by electromagnetic induction.

The second is the hydraulic RSA. This RSA can harvest energy by employing oscillatory motion to drive the power generator. Some studies reformed the existing hydraulic shock absorber and utilized the oil in the shock absorber to flow into a parallel oil circuit. They usually used the flowing fluid to drive a hydraulic motor connected in parallel to a DC/AC generator [40].

The third category is the mechanical RSA, which was developed quickly because of its greater efficiency and average power [38]. The general architecture of said RSA using supercapacitors, which are applied to extend the battery endurance, has four main parts: (1) the suspension vibration input module, (2) the transmission module, (3) the generator module, and (4) the power storage module, as shown in Figure 3.

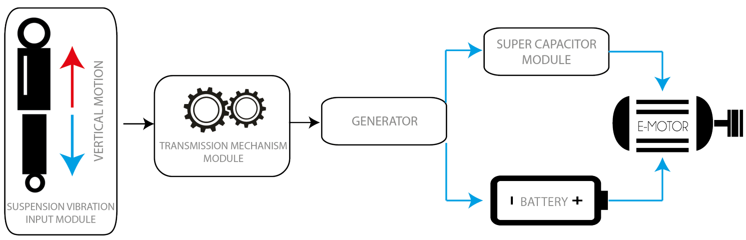

Figure 3. A diagram of the configuration of an RSA-ER.

2.1.3. Regenerative Braking Extended Range RB-ER

The EV's motor can work as a generator under deceleration procedures, charging the battery and exerting regenerative braking torque on the axle simultaneously, as shown in Figure 4. A regenerative braking system (RBS) can capture the kinetic energy of an electric vehicle during the deceleration process, thereby improving the EV's energy efficiency. For an EV, friction and regenerative brakes generate brake torque, either separately or together [41]. In addition, the use of an adequate control strategy helps to reduce the loss rate; for example, the revised regenerative braking control strategy (RRBCS) can reduce inefficiency at the expense of slight braking energy recovery loss. Thus it positively affects prolonging the battery's life while ensuring braking safety and maximal recovery energy [42].

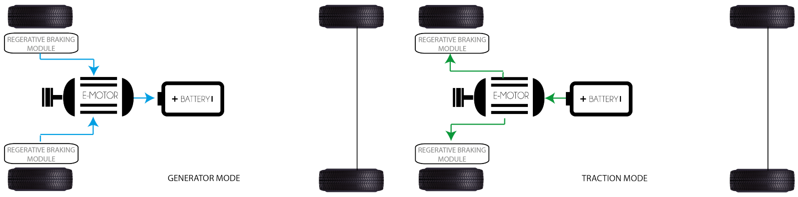

Figure 4. The configuration of an RB-ER. Energy flow: left generator mode and right traction mode.

An EV with automatic mechanical transmission (AMT) has higher transmission efficiency because it uses a composite braking process. The braking force of the motor varies according to the transmission gears at the same speed. Therefore, when the vehicle is braking, the transmission gear can be shifted reasonably according to the vehicle's condition. This mechanism improves the EV economy, since it allows the motor to work efficiently while recovering the braking energy to the maximum extent. An appropriate strategy can effectively improve the energy recovery rate and ensure braking safety and stability [43].

2.1.4. Fuel Cell Extended Range (FC-ER)

Fuel cells (FC) are electrochemical energy conversion devices that convert chemical energy directly into electrical energy and heat [44]. The electrochemical transformation is a chemical reaction of oxidant and reductant to produce electricity and water in stack output [45].

An anode, a cathode, and an electrolyte are the main components of an FC; water and electrical energy are the products. In the process, the anode supplies hydrogen, and the cathode terminal supplies oxygen [46]. During the reaction, hydrogen decomposes into positive protons and negative ions on the anode side. The resulting positive particles reach the cathode tip through the electrolyte, allowing only the positively charged particles to pass. The electrons, the negative ions at the end of the anode, tend to reunite with the positively charged particles and pass to the cathode side through an external circuit. This electron flow in the external circuit generates electricity. The electrons passing to the cathode side combine with positively charged particles and oxygen to produce pure water and heat, as shown in Figure 5 [1,47–53].

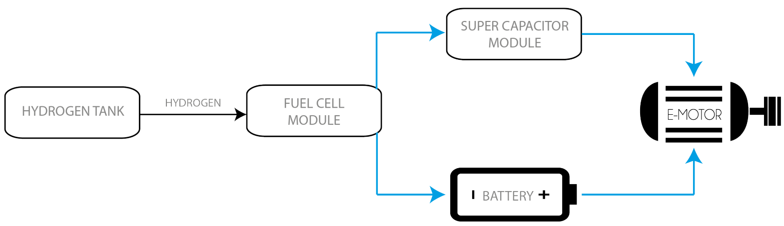

Figure 5. A diagram of the configuration of FC-ER.

2.1.5. Micro Gas Turbine Extended Range (MGT-ER)

Microturbines (MGT) are small gas turbines with output power levels of 30 to 500 kW [54]. A MGT mainly consists of a single-stage radial compressor, a radial turbine section, and a recuperator. They usually use foil bearings (air bearings). The typical cycle of an MGT consists of four processes:

1. A radial compressor compresses the inlet air.
2. Air is pre-heated in the recuperator using heat from the turbine exhaust.
3. Heated air from the recuperator is mixed with fuel in the combustion chamber and burned.
4. Hot gas expands in turbine stages, and the gas's energy is converted into mechanical energy to drive the air-compressor and the drive equipment (usually generator).

Automakers claim that the gas turbine is the most efficient solution that is on its way. In particular, MGT can be an alternative to the ICE as a RE for EVs. The MGT produces less raw exhaust gaseous emissions, such as hydrocarbons and carbon monoxide, and has more static applications compared to the ICE. In addition, any MGT is lighter than the equivalent ICE, and it provides a potential reduction in the level of carbon dioxide produced [55–57]. Figure 6 shows the configuration of an MGT-ER connected to a generator and in series with a battery.

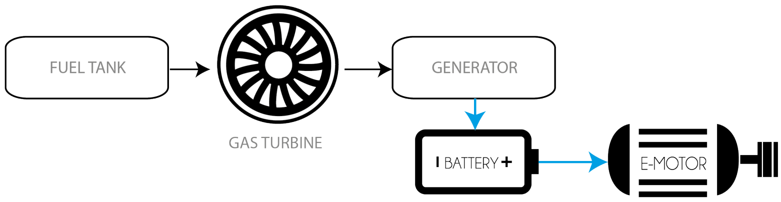

Figure 6. A diagram of the configuration of MGT-ER.

2.1.6. Thermoacoustic Engine Extended Range (TAE-ER)

Most vehicles waste nearly a third of their fuel's energy through the exhaust. Therefore, an efficient waste heat recovery process would undoubtedly improve fuel efficiency and reduce greenhouse gas emissions. Multiple waste heat recovery proposals exist. One of these is the thermoacoustic converter (TAC). The engine exhaust (hot side) and the coolant (cold side) produce a temperature differential that the TAC uses to produce electricity. Essentially, the TAC converts exhaust waste heat into electricity in two steps:

1. The exhaust heat is converted to acoustic energy (mechanical);
2. The acoustic energy is converted to electrical energy [58].

Three main stages illustrate how a TAE functions. The first is fuel burning in the combustion compartment, containing the combustion chamber blower and the combustion chamber. The second is the hot exhaust gases heading into the hot heat exchanger, transferring heat to the working fluids through a heat pipe. The third is the stack, which is the TAE's thermal module area and is surrounded by a hot and cold reservoir on each side, exchanging heat. The cold reservoir exchanges heat through the cold HEX with the ambient air [59,60]. Figure 7 shows a diagram with the main components in a TAE-ER.

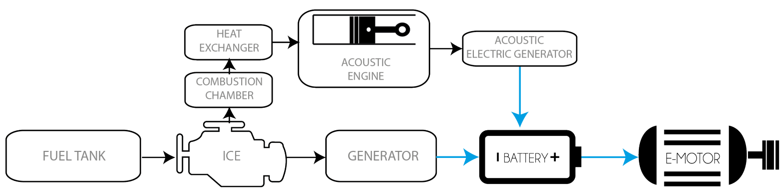

Figure 7. A diagram of the configuration of TAE-ER.

2.1.7. Flywheel Energy Storage Extended Range (FES-ER)

A flywheel energy storage (FES) system has fast charge/discharge, is infinitely clean, and is highly efficient. The system consists of three energy storage components: a flywheel, a battery, and an ultra-capacitor. A flywheel is a rotating disk used as a mechanical energy storage device [61]. Two classes of materials are commonly used to fabricate the flyWheel, steel and composite materials. The difference is their rotational stress limitations. A composite-based flywheel can support higher speeds and rotational stress thresholds than a steel-based one. Therefore, composite materials can be used at high speeds (up to 100.00 rpm), whereas lower speeds (up to 10.000 rpm) apply to steel-based flywheels, which are heavier than the composite ones. The main limitation for the use of the composite material is its cost [62]. As a kind of short-term energy storage system, the FES system cannot be the primary power source of the vehicle. Therefore, a FES system with high power density is often used as an APU for a vehicle. The FES works while the vehicle brakes; it absorbs the RB energy. When the vehicle needs to accelerate, the FES system and the battery provide energy to the vehicle [31], as shown in Figure 8.

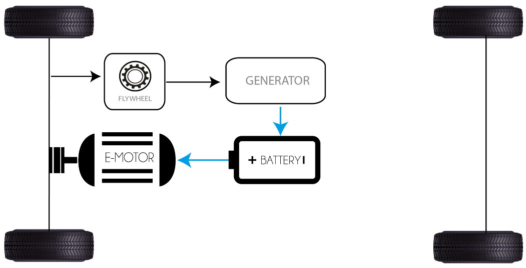

Figure 8. A diagram of the configuration of FES-ER.

2.1.8. Solar Energy Storage Extended Range (SES-ER)

Solar photovoltaic cells (PVCs) generate electricity by absorbing sunlight and converting it to electric current. Vehicle companies favor solar energy storage (SES) systems for their cleanliness, safety, and economic performance. Studying efficient and stable SES systems has become critical for many automobile enterprises [63]. A car using a PVC improves autonomy by about 10% when used in a city [64]. Ezzat et al. [65] proposed a novel comprehensive energy storage system for EREV. The energy storage system proposed consists of PVCs, an FC, and batteries. The results showed that the addition of solar cells to the energy storage system of EREV could improve energy efficiency, perfectly complementing a range extender. Figure 9 shows the configuration of an FES-ER.

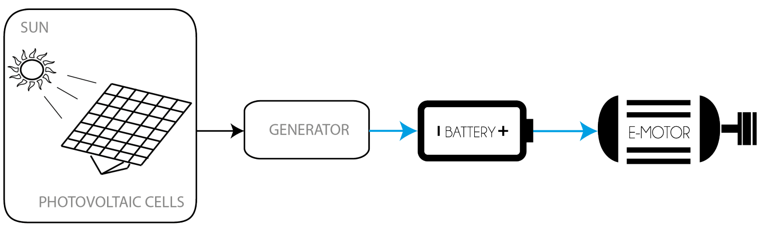

Figure 9. A diagram of the configuration of SES-ER.

2.1.9. Rotatory Engine Extended Range (RE-ER)

Rotary engines (REs) are small in size, and their high power output makes multiple electrification technology solutions possible via a shared packaging layout. The rotary-powered range extender takes advantage of their compatibility with gaseous fuels: it works by burning liquefied petroleum gas to provide a source of electricity. A rotary engine has only two moving parts: the rotor and the shaft are inherently balanced with no oscillating components and produce minimal vibrations [66]. Each crankshaft revolution produces one rotor revolution, a complete engine cycle in each of the four chambers, and four power strokes [67]. Figure 10 shows the configuration of RE-ER.

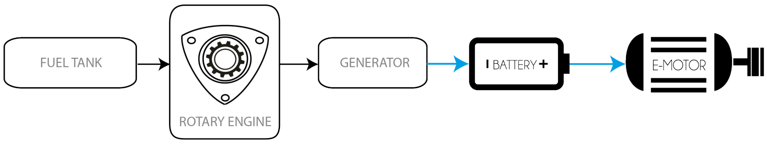

Figure 10. A diagram of the configuration of RE-ER.

Hydrogen combustion in a RE was carried out by Zambolov et al. [68], which complements the research about REs.

2.1.10. Wind Turbine Extended Range (WT-ER)

When a vehicle moves, it experiences wind resistance in two different forms—frictional drag and form drag. Frictional drag arises due to the viscosity of air, and form drag arises due to air pressure variation in the front and rear sides of the vehicle [69]. Suppose this wind energy is used to extract some power, not to create any component of force or thrust opposite the direction of the vehicle's propulsion. In that case, the energy can produce electricity to charge up the EV battery itself. [66,70,71] presented a conceptual design of harnessing wind's power to generate extra energy. Those designs can provide energy which could be stored or directly used to power electronic devices and vehicle instrumentation in a car or truck in movement. The use of wind energy in an EV can have different configurations, depending highly on the vehicle. One must not increase the drag coefficient to an extent that risks recovering the energy inefficiently. Figure 11 shows the configuration of WT-ER.

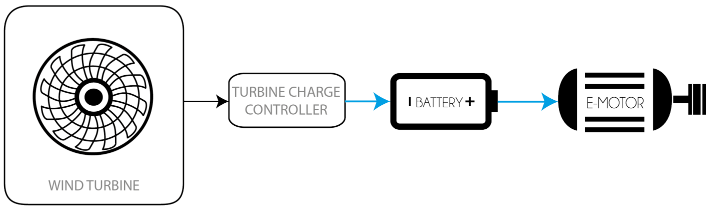

Figure 11. A diagram of the configuration of wind energy extended range.

3. A Comparison of the Technology Used in EREVs

When we design an extended range electric vehicle, we start by comparing the different technologies, analyzing their possible configurations, and analyzing the relationships among all their components.

The selection of the type of range extender at the time of vehicle design will depend on certain system characteristics. Thus, range extender systems are compared here. The criteria by which the systems are evaluated are as follows.

- System power;
- Amount of extra range;
- Global system efficiency;
- Emissions.

Vehicle concepts can have diverse sets of specifications. For example, the battery size and user profile determine the amount of time a range extender is used. This defines the importance of the efficiency. Furthermore, depending on the type of vehicle, the packing weight can be a more or less important criterion for choice of technology.

A brief overview of the collected information is presented in Table 1. It is clearly possible to identify that there are major differences between some of the concepts.

Table 1. A comparison of the extended range systems.

Extended Range System	System Power	Extra Range	Efficiency	Emissions
ICE-ER	30 kW [12] 35 kW [14] 5.5 kW [35] 111 kW [72]	232.79% [7] 430 km [12] 51–139 km [35] 380 km [73] 330 km [74] 676 [72]	20–40% [75,76] 31% [12]	Low
Fuel cell-ER	20 kW [77] 85–83 kW [78] 1200 W [47] 25 kW [79] 128 kW [80]	500 km [77] 650 km [80] 665 km [81] 594 km [81] 1500 km [82]	70% [77] 63.6–72.4% [83] 43% [47] 55.21% [79]	No
Rotary engine-ER	3.8 kW [84] 20 kW [85]	80 km [85] 321 km [86]	73% [87] 78% [84] 77% [85]	Low
RB-ER	14.8 kW [88] 55.75–82.66 kJ [89] 298.75 kJ [90]	32.1–47.7% of the total recoverable energy [89] 1.18% SOC improve [90]	79–94% [88] 30–60% [26] 47% [89]	No
MGT-ER	32 kW [91] 100 kW [92] 63.3 kW [93]	370 km [94]	47.2% [95] 28% [91] 30% [92] 35% [94] 38% [93]	Low
PVC-ER	68.2–300 W [96]	19.6 km [96]	91.2% [96] 20.2–23% [96]	No
WT-ER	2.64 kW [97] 0.1–1.1 kW [70]	add up to 10% [98] 7.27 km [97]	75% [97] 75–90% [70]	Low
FES-ER	40 kW to 1.6 MW [99] 60–101 kW [100] 1–20 kW [101]	50% milage over [100] 1.17% milage over [102]	60% [100] 90–95% [103] 70–90% [104]	No
TAE-ER	710 W [105] 1029 W [106] 58 W [107] 1.5 kW [108]	80% fuel consumtion savings [59]	33.8–38.7% [60] 30% [105] 5.4% [106] 18% [78] 16% [108]	Low
RSA-ER	8–40 W [100] 0.74–0.78 kW [109] 19.2–67.5 W [110] 4.3 W [38]	Can power an 8 W lidar for 323 days or a 2 W camera for 1292 days [100]	70–80% [100] 71–84% [111] 33–63% [110] 87% [38] 16% [38]	No

The increasing demand for extended driving range in electric vehicles is the most prominent factor driving the EREV market. As a result, the global EREV market is projected to reach more than 500,000 units and more than $1500 million by 2026, at a compound annual growth rate (CAGR) of between 9.0% and 11.89% [112]. The Asia–Pacific market is estimated to reach more than $750 million by 2026, with a CAGR of 8.1%. North American market is estimated to reach more than $340 million by 2026, at a significant CAGR of 10.6% [113,114].

Major industry participants are further investing a substantial amount into research and development processes to create advanced range extender products using various technologies. The top 10 automotive component manufacturers include the following: Magna offers a hydrogen fuel-cell platform as a range extender for battery electric vehicles. MAHLE offers an electric range extender engine for EVs to original equipment manufacturers (OEMs). The company's range extender engine offers an electric range extension of 65 km. Rheinmetall offers heater/cooler modules for extending the driving ranges of electric buses. Plug Power is developing a fuel cell range extender electric vehicle that can extend the driving range by approximately 136 km. AVL offers the entire range of powertrain systems for extended-range electric vehicles. The five other leading players are Ballard Power Systems, FEV, Delta Motorsport, Ceres Power, Nissan, General Motors, and BMW [112].

Many OEMs have integrated some of the RE technologies into mass production vehicles. Companies such as Chevrolet with its Volt model [72], BMW with its I3 and I3Rex models [73,74], and Honda with its Clarity model [115], have incorporated ICEs as range extenders. Brands such as Toyota with its Mirai model [80], and Hyundai with its Nexo model [81], have incorporated fuel cells as range extenders in light vehicles; NIKOLA MOTORS has included fuel cells in trucks, giving them autonomy for around 1500 km [82]. Mazda incorporated a rotary engine in its model Mazda 2 [86] and plans to incorporate the same technology in SUVs in the future. The heavy duty truck OEM MACK is using an MGT to extend the ranges of their vehicles. In its Karma model, Fisker placed photovoltaic cells over the entire roof of the vehicle to recover energy. It is worth mentioning that regenerative braking is used in almost all mass-produced light EVs and even in trucks such as the MACk LR model with a power output of 780 kW [116].

The market share of hybrid vehicles with alternative energy represents 0.7% of the total sales of all cars marketed until the middle of 2021. As of the end of 2020, sales were 0.6% in North America. Referring to EVs with ICEs to extend their ranges, Honda's Clarity and Chevrolet's Volt have market shares of 4% and 0.1% respectively. Furthermore, concerning EVs with fuel cells to extend the range, there is Toyota's Mirai model and Hyundai's Nexo model with 3.1% and 0.3% [117,118].

3.1. EREV Configuration

The system for power transmission in an EREV includes an APU, an electric motor, and a battery. Other components complement the system, such as the DC-DC converter and an electronic controller, but these components do not define the vehicle's configuration. The electric motor is the main component that defines the configuration of an electric vehicle or extended-range electric vehicle. The configuration of the vehicle is determined by the position of the electric motor and by the technology. The electric motor can be in a longitudinal or lateral position, and it can be at the front or the rear of the vehicle. The electric motor transforms electrical energy into mechanical energy and transmits it to the wheels, but it can also have a gearbox and a mechanical differential. If the car has an electric motor for each wheel, or if the motors are inside the wheels, the differential system must be electronic.

An EV and its APU contribute three factors of major importance:

1. The traction force, which can be forward, backward, or four-wheel drive.
2. The position of the engine.
3. If it has a gearbox and the type of differential, mechanical or electronic.

The type of configuration is studied and analyzed in order to optimize the topology better. The batteries are left aside and only are under consideration for the type of traction, the direction that the EV will have, the gearbox, and the final transmission ratio. The APU can be positioned regardless of the vehicle's configuration. The electric motor is the only one that provides power to the wheels.

EREV Topological Configurations

The EREV configuration combines the ICEV and EV configurations. It attempts to integrate the best parts of each one, and it is relatively flexible. This flexibility is due to several factors unique to the EV. An EREV works like an EV. First, the energy flow is mainly via flexible electrical wires rather than rigid and mechanical links, achieving distributed subsystems. Second, different EREV propulsion arrangements produce significant differences in system configuration. Third, different energy sources (such as auxiliary power units) have different characteristics and refueling systems. In general, the EREV consists of three major subsystems. Electric propulsion, which comprises an electronic controller, a power converter, an electric motor, mechanical transmission, a final drive, and driving wheels. An energy source, which involves the energy source, energy management unit, and charger. An auxiliary power unit, which consists of the generator, and depending on the technology, an ICE, a fuel cell, regenerative braking, regenerative shock absorbers, a flywheel, a thermoacoustic engine, photovoltaic cells, a gas turbine, a rotary engine, and a wind turbine/refueling unit. The energy management unit cooperates with the electronic controller to control regenerative energy and its energy recovery. It also works with the energy charger and monitors the usability of the energy source.

At present, there are many possible EREV configurations due to the variations in electric propulsion and energy sources. Thirteen alternatives focus on electric propulsion variations; some are in typical vehicles, and others are in high-performance vehicles.

(1) All-wheel drive (AWD; Figure 12a) is the first alternative, a direct extension of the existing ICEV adopting a longitudinal front engine. It consists of an electric motor, a gearbox, differential, an APU, battery, and a BMS connected to the electric motor; this configuration has two differentials to transmit the power to both axles.

Figure 12b shows a typical configuration for pick-ups and high-performance sedan vehicles. The electric motor changes its orientation from longitudinal to cross-wise, maintaining a gearbox, two differentials, an APU, a battery, and a BMS. Figure 12c shows one electric motor in each axle; this configuration keeps a gearbox coupled with the motor. The gearbox can be single-gear or two-gear to multiply and divide torque and revolutions. Figure 12d shows an electric motor for each wheel. The mechanical differential is replaced by an electronic differential that controls the speed differentiation of one wheel concerning the other. This type of configuration uses small, high-efficiency electric motors. Figure 12e shows a configuration with in-wheel motors. Again, one variant can have no gearbox. In this configuration, the electric motor has high efficiency and high velocity. The electric motor is connected directly to the wheel, and the other components are like those in the previous configurations. Figure 12f similarly uses in-wheel motors but simultaneously incorporates an electric differential, maintaining an APU, a battery, and a BMS; each wheel efficiently transmits power and reduces weight compared to other configurations.

(2) Front-wheel drive (FWD; Figure 12g). In this configuration, the electric motor changes from longitudinal to cross while maintaining the same components as the all-wheel-drive configuration. The difference is that the mechanical power transmission is only to the front wheels, and it can have an electric motor for each wheel with or without a gearbox. Figure 12h shows a configuration in which an electronic differential replaces the mechanical one. Figure 12i shows a similar configuration using electric motor in-wheel technology while keeping the battery, the BMS, and the APU.

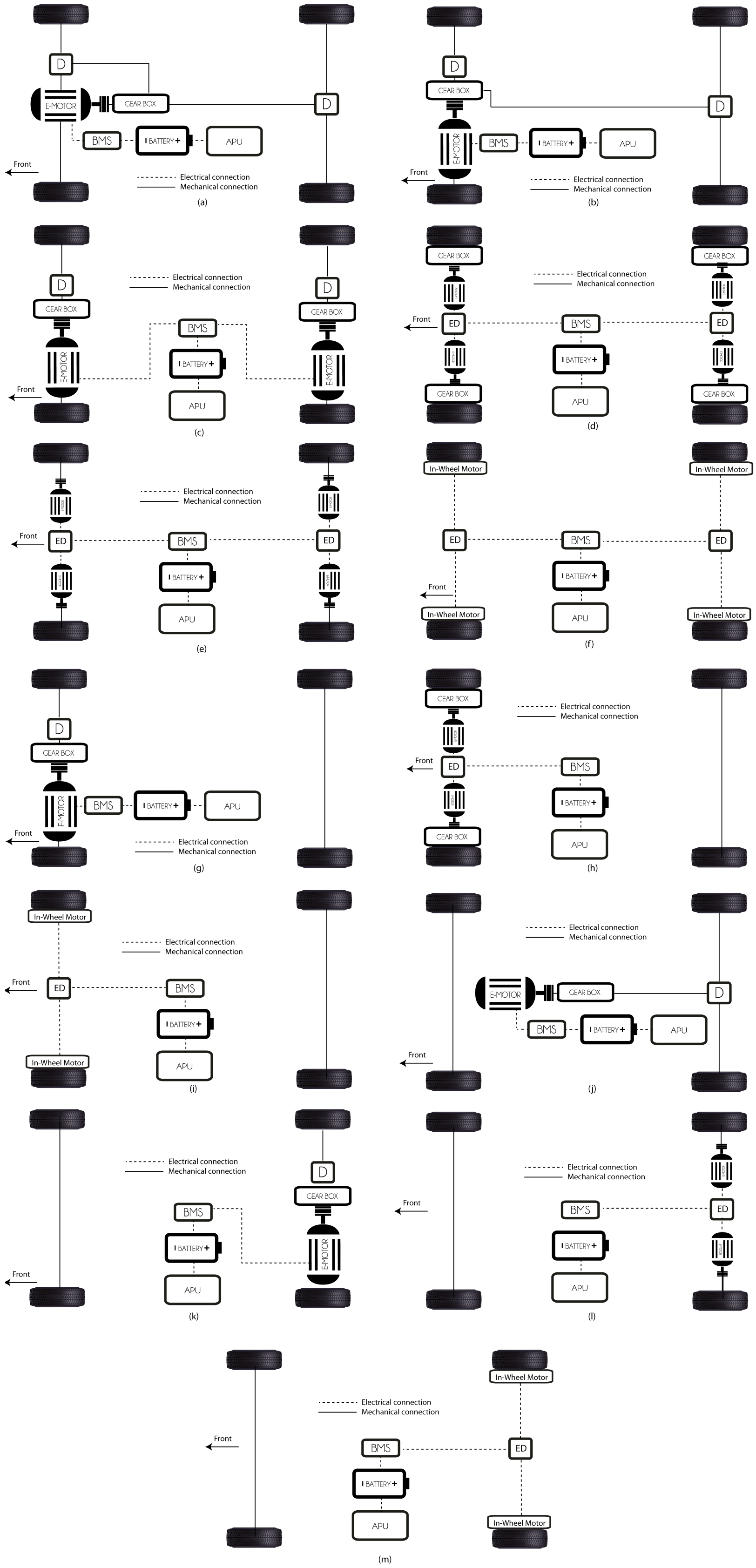

Figure 12. All possible EREV configurations.

(3) Rear-wheel drive (RWD) maintains a longitudinal electric motor in Figure 12j, but the rear wheels receive the mechanical power. In Figure 12k, the significant from

with the previous one is the position of the electric motor; it changes from longitudinal to cross; the rest of the components are the same. A configuration that improves the performance is having an electric motor in each wheel, with or without a gearbox, as shown in Figure 12l. Figure 12m shows the last configuration, which uses the electric motor in-wheel with electric differential. The selection of the configuration will depend on the size and application of the EREV. The primary criteria for selection are compactness, performance, weight, and cost.

Using driving cycles lets us know the emissions released and the energy consumption. However, due to the complexity and diversity of the vehicles, it is not easy to simulate a whole vehicle fleet using a physical approach [119], so we can use some software to estimate the emissions and energy consumption. Software such as MATLAB-Simulink, AVL Cruise, ADAMS, ANSYS, ADVISOR, ANSOFT, and MAPLESim can simulate driver/vehicle systems.

3.2. Key Components of an EREV

First, vehicle weight directly affects performance, especially the range and gradeability. Lightweight materials such as aluminum and composite materials for the body and chassis help with weight reduction. Second, achieving a low drag coefficient with the body design effectively reduces aerodynamic resistance, significantly extending the range of the EREV on highways or when cruising. The aerodynamic resistance can be reduced by tapering front and rear ends, and adopting a flat, covered, low-floor design. One can also optimize the airflow around the front and rear windows while using this flow to cool the batteries to minimize battery losses efficiently. Third, low rolling resistance tires effectively reduce running resistance at low and medium driving speeds and play an essential role in extending the range of EREVs in city driving. The design of an EREV requires considering the interactions of all the components that it may have. Figure 13 shows all the main components and the interactions that they may have with each other.

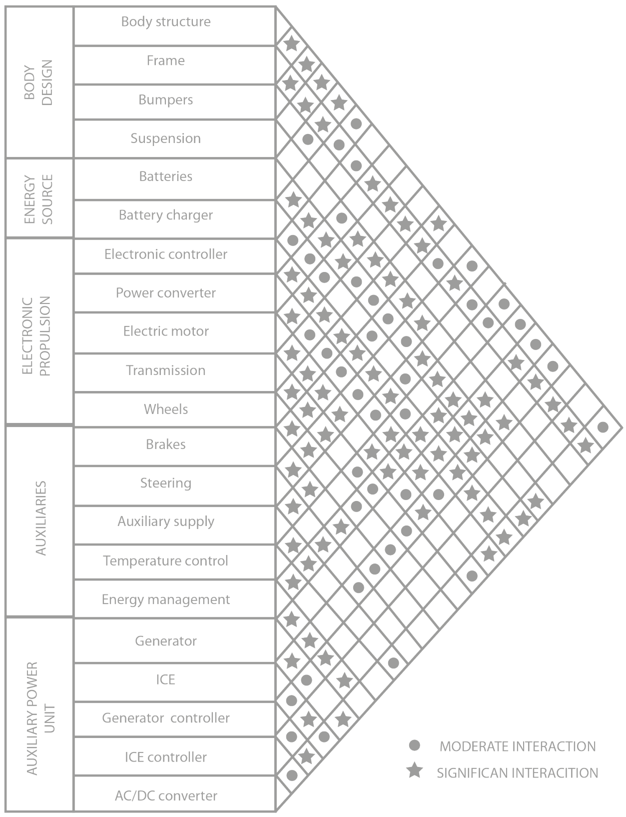

Figure 13. Key components and interactions.

4. Control and Management

The control issue of power electronic interface converters plays a vital role in the efficient and safe operation of EREVs. There are many studies on the control of power flow and energy management. Table 2 shows studies about energy management methods. The control and management strategies are focused on (1) minimization of fuel consumption and loss of energy, (2) simplifying the structure, (3) increasing the maximum efficiency, and (4) ensuring robustness and satisfactory driving performance. Energy management: Adopting an intelligent energy management system (EMS) helps maximize onboard stored energy. Using sensor inputs, such as air temperature and currents and voltages for the motors and batteries, among other data, the EMS can perform the following functions:

1. Optimize the system's energy flow;
2. Predict the remaining energy and hence the residual driving cycle;
3. Turn on the APU to charge and improve the autonomy with a suitable control method;
4. Suggest more efficient driving behavior;
5. Direct energy regenerated from braking to receptive energy sources such as the batteries;
6. Modulate temperature control as a response to external climate;
7. Propose battery charging;
8. Analyze the operation history of the energy source, especially the battery;
9. Diagnose any incorrect behavior or defective components of the energy source, or malfunctions of any component.

Table 2. A summary of control methods and strategies for EREVs.

Control Methods/Strategy	Author	Controlled System	Technology	Purpose	Application
Constant power control strategy	[3]	BMS	ER-ICE	The lowest permissible level of SOC after the drive charge the vehicle	Charging Management Arterial Roads
A power follower control strategy	[3]	BMS	ER-ICE	The lowest permissible level of SOC after the drive charge the vehicle	Charging Management Express Way
Proportional resonant control strategy	[8]	Generator	ER-ICE	To maintain the efficient region of the generator	Generate more energy
Partial power following control strategy	[8]	ICE	ER-ICE	To maintain the efficient region to operate the ICE	Reduce fuel consumption
A control strategy based on Pontryagins Minimum Principle (PMP)	[9]	ICE	ER-ICE	Monitors the current SOC of the battery	Minimizes the energy consumed during driving
Predictive control-based energy management	[90]	Fuel Cells	ER-FC	Forecasted speed	Minimize hydrogen consumption
Regenerative Braking control strategy (RRBCS)	[28]	Regenerative braking	ER-RB	The better capacity of the regenerative braking energy consider slip ratio of the tire	Coordinate regenerative braking torque and mechanical friction to maximize energy recovery and to ensure the braking efficiency

Table 2. *Cont.*

Control Methods/Strategy	Author	Controlled System	Technology	Purpose	Application
A normal control strategy based on a state of charge (SOC)	[12]	ICE	ER-ICE	Monitors the battery state of charge (SOC)	Reduce CO_2 emissions
Automatic Mechanical Transmission (AMT) Shift control strategy	[43]	Regenerative braking	ER-RB	Identify the braking intention and transmission shifts correctly	Improve the braking energy recovery rate, and ensure the braking safety a stability
Start-stop control strategy	[33]	ICE-Generator	ER-ICE	Reduce the start-stop times and running time	Fuel economy
Adaptive power management strategy PMS	[18]	ICE	ER-ICE	Asses the battery SOC and vehicle speed	Improve energy savings, the fuel, and electrical consumption
Method of quantitative estimation	[120]	Generator	ER-ICE	Optimize the design parameters aiming at the maximum efficiency in the continuos rated	Find maximum torque per ampere
Charge-deplete-charge-sustain (CDCS) strategy	[15]	ICE-Generator	ER-ICE	Asses the battery SOC and vehicle speed	Energy efficiency, reduce energy consumption and reduce costs of operation
Thermal management system to battery cooling strategy	[22]	Battery	ER-ICE	Quantify the heat generation sources and accurately predicting cell temperatures	Improve longevity, safety, and overall performance
A data driving behavior predictive control strategy	[23]	Driving behavior	ER-ICE	Predict the EV power requests and optimize their control inputs	Improving the driving range and battery life while maintaining thermal comfort for the passengers
Mixed-integer convex program	[37]	Powertrain	ER-ICE	Formulate an economic optimization	All the quantities to minimize are expressed as a monetary variable
The convex optimal control problem	[36]	Powertrain	ER-ICE	Optimization over the entire driving cycle is computed offline	Achieve the best possible energy consumption.
The optimal operation curve control strategy	[29]	ICE	ER-ICE	Research and control the vehicle required torque	Control the power allocation of APU and batteries to reduce fuel consumption and obtain good fuel economy
Multi-objective hierarchical prediction energy management strategy	[52]	Fuel cells	ER-FC	Propose a Global state of charge rapid planning method based only on the expected driving distance	Achieve optimal fuel cell life economy and energy consumption economy
A novel energy-aware velocity planning	[32]	ICE	ER-ICE	Propose energy-aware velocity planning	Improve electric vehicle fuel efficiency
Pseudospectral optimal control	[34]	APU	ER-ICE	Maintain engine speed constant is better for the dynamic characteristics of APU	Different limits of the APU power changing rate significantly influence the fuel consumption
Model predictive control	[121,122]	Powertrain	ER-ICE	Propose a computationally tractable model prediction control (MPC)	Prediction horizon so that energy consumption is minimized

5. System Optimization

As mentioned before, EREVs have complex architectures that contain multidisciplinary technologies. Since the EREV performance can be affected by many multidisciplinary, interrelated factors, computer simulations are the most critical technology with which to optimize performance and reduction costs. Additionally, EREV simulations can help manufactures to minimize prototyping costs and rapidly evaluate their concepts. Since an EREV's system consists of various subsystems clustered together by mechanical, electrical, control, and thermal links, the simulation should be a parameterized mixed-signal one. Hence, optimization is at the system level, at which there are many tradeoffs among various subsystem criteria. The preferred system criteria generally involve numerous iterative processes. In summary, the system-level simulation and optimization of EREVs should consider the following key issues.

1. As the interactions among various subsystems significantly affect the performances of EREVs, the significance of those interactions should be analyzed and taken into account.
2. The model's accuracy is usually correlated with the model's complexity, but the latter may run counter to usability, tradeoffs among the accuracy, complexity, usability, and simulation time should be considered.
3. The system voltage generally causes contradictory issues for EREV design. For example, the battery weight (higher voltage requires more battery modules in series, and hence more weight for the battery case). Similarly, motor drive voltage and current ratings, auxiliary power unit range, energy generated, acceleration performance, driving range, and safety should be optimized at the system level.
4. The adoption of multiple energy sources helps to increase the driving range. For the EREV case, the APU should be optimized based on the vehicle's performance and cost requirements.

5.1. Controller Optimization for Plant

In an EREV, a plant could be an ICE, an electric motor, or a battery. Different strategies can optimize the plant and its controller: sequential, iterative, bi-level, and simultaneous strategies [123]. Sequential optimization often leads to non-optimal system designs due to plant/controller optimization coupling. Iterative plant/controller optimization strategies attempt to improve the initial design by first improving the plant design without compromising control performance and optimizing the controller design without compromising plant performance. In a bi-level plant/controller optimization strategy, two nested optimization loops are used. The outer loop optimizes the scalar-substituted objective function by changing only the plant's design. The role of the inner loop is to generate the optimal controller for each plant selected by the outer loop. The simultaneous strategy can be mathematically and computationally challenging for several reasons. The simultaneous plant/controller optimization problem is a hybrid static/variational problem. Even when the plant and controller optimization subproblems are convex, the collaborative problem is not guaranteed to be convex. Figure 14 shows the strategies for plant/controller optimization.

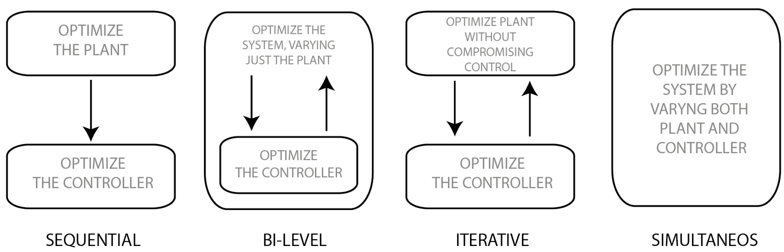

Figure 14. Strategies for plant/controller optimization.

5.2. Multidisciplinary Optimization

It is necessary to capture the effects of each energy domain on the dynamics of the other domains to optimize a system. For example, when analyzing extended-range electric vehicles, the generator and internal combustion engine coupling should be optimized to provide the energy needed to charge the batteries and increase the vehicle's autonomy.

EREV power trains reduce design space for the remainder of the physical system and increase the complexity of the control. The coupling (dependency) among the parameters of the physical system (e.g., topology) and the control parameters transforms the problem into a multi-level problem, as depicted in Figure 14. If solved sequentially, it is by definition sub-optimal [124]. Therefore, the physical system and the control should be designed in an integrated manner to obtain an optimal system. Due to the oversized dimensions of the design space, computer simulations of dynamical systems have become more important as a preliminary step to building prototypes, e.g., for different architectures and component sizes. Computer simulations significantly speed up the control synthesis of a given design and topology. However, even with computer systems, finding the optimal vehicle design that provides the best control performance is typically intractable. It is not feasible (cost or time-wise), given design space, to build all possible vehicles and evaluate which configuration and parameters provide the best control performance.

5.3. Optimal Control

There is tight integration between the physical design and an element's control from a dynamics perspective. A sequential design process is often used to design the physical system, which is followed by control-system design [125]. In EREVs, we need to know the functions of all components and their interactions to generate the best possible control systems. The simulations are important because they predict system behavior given the specifications provided. However, a simulation can also be used for the inverse task: identifying system specifications that produce the desired behavior.

5.4. Size Optimization

It is essential to optimize the sizing of propulsion system components without reducing performance to reduce the manufacturing costs and emissions associated with transport platforms. In a conventional vehicle, the size of the ICE is directly associated with the maximum power required for the vehicle. Similarly, in the case of pure electric vehicles, the range depends on the size of the battery. In general, it is the energy rather than the power that conditions the sizing of the batteries. There is not total freedom of design in either platform, because a single energy source powers the vehicle in both cases.

Extended-range electric vehicles have at least one degree of design freedom, that is, the sizes of their energy sources, because more than one energy source is integrated. The sizing of an EREV platform consists specifically of defining the size requirements in terms of power and/or energy. Then, the sizes of the energy sources and the vehicle's power requirements implicitly define the sizes of the power converters that make up the propulsion system. The choice of component size significantly affects vehicle's performance in terms of power availability, energy efficiency, manufacturing costs, and component life. Figure 15 shows the strategies for plant/controller optimization.

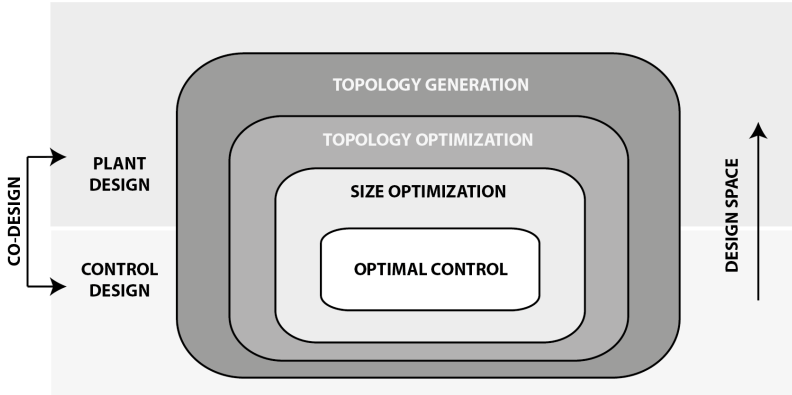

Figure 15. Optimization levels of an EREV.

6. The Process of Designing an EREV

Here we present a guide for designing an extended-range electric vehicle in general terms.

Once the kinds of technology have been analyzed and compared, after knowing the possible configurations and the interactions of the components, a conceptual design of an extended range electric vehicle can be generated. However, first, we must define the type of vehicle we are going to design. There are three types that cover the vast majority of vehicles, and they are compacts, pick ups, and trucks.

As a second step, depending on the type of vehicle we want to design, we select the type of traction that this may have, which varies depending on the type of vehicle; the three main types are FWD, RWD, and AWD.

As a third step, we define the technology of the electric motor that the EV will have and its position for its configuration. In-wheel motors are commonly used in compact vehicles.

As a fourth step, we have the selection of the range extender system. We can make our selection under certain criteria, and we are helped by Figure 16, where we compare these technologies. For practice, we define two selection criteria: the amount of power and the emissions. Large vehicles need high levels of autonomy; small vehicles can have medium or low levels of autonomy. Our selection criteria are the extra range needed, a high, medium, or low amount; and the space and weight that can be sacrificed.

As a fifth step, the controller selection (independent or general controllers) will depend on the control strategy to use; we can consult Table 1.

We can also optimize the controller selection (see Section 5) using the strategies shown, and our components' sizes.

Then, we will finally have our extended range electric vehicle, which should have ideal performance, optimal control, and optimized components. All steps are shown in Figure 16.

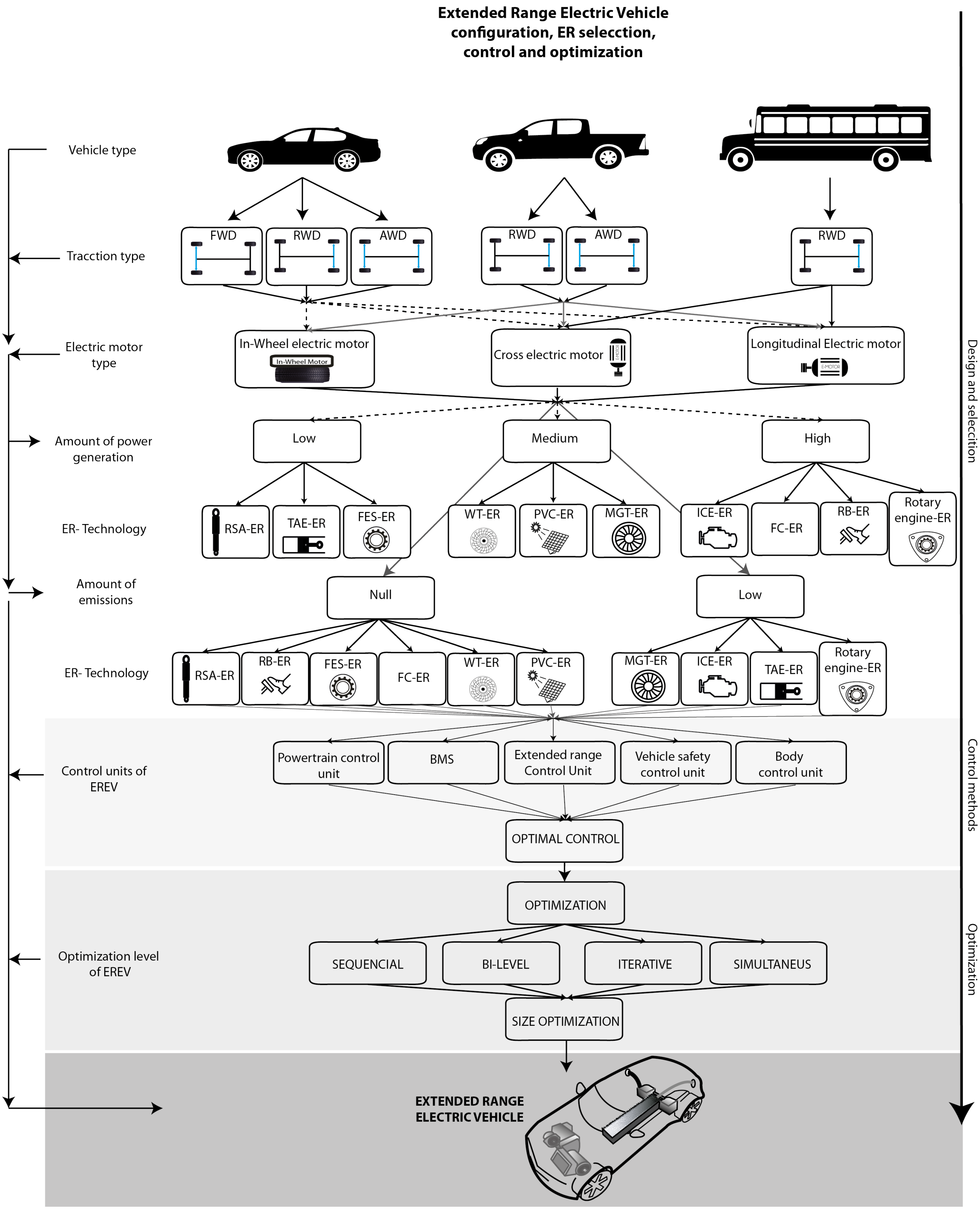

Figure 16. The process of designing an EREV.

7. Discussion

This paper reviewed the current technologies, control methods, optimization methods, and design methods for EREV vehicles, including the architecture, key components and their interactions with each other, the sizing of components, and methods to find the optimal system-level design. Although at first glance, there seem many different configurations, the most commonly used have an electric motor in the central position. However, the use of an in-wheel motor is typical if the vehicle has high performance. The central aspect to consider with the technologies used to recover energy and increase autonomy is the cost of implementing them. Some technologies are more economical and easier to control. Additionally, the fuel or resource cost for the range extender to work is a limiting factor for integration and profitability; it helps the electric vehicle concerning autonomy. All the technologies presented in this work aid electric vehicles. Depending on the budget that each researcher or research center has, it can implement and carry out tests to verify and optimize the implementation of the selected technologies. Currently, the combustion engine is the most common technology used to increase autonomy. That is why most researchers seek to reduce ICEs' fuel consumption to increase energy efficiency and recover energy. By analyzing the literature, we can conclude that the use of optimization methods will depend on the scope of the research, but usually involves finding the most efficient configuration of all components, thereby solving different optimization layers for design. These could be further used in more extended coordination methods to include the selection of topologies and technologies. For instance, these extended coordination methods might include: (i) simultaneous topology and sizing design, alternating with controller design; (ii) controller design nested for simultaneous topology and sizing, (iii) topology alternating with sizing or control; or (iv) simultaneous topology, sizing, and control design. We have presented a guide for determining critical components and the interactions between them in order to design a new topology and optimize all levels depending on the technologies used.

To substantially reduce the computational burden, the introduction of approximations of the original problem should shorten the driving cycle used for design, or one should use parallel computing. Driving cycles used as input for the control (energy management strategy) or any simulation should be short, realistic, and representative of realistic driving types. In some cases, it is necessary to create a personalized driving cycle to analyze the behavior of the extended-range electric vehicle concerning energy consumption, range, and emissions. A problem that remains open is how to address multiple topologies with a large variety in terms of component types and quantities in a more intuitive way. In addition, optimization problems and automatic construction of topologies spur on the development of control algorithms that automatically handle various topologies. Optimization objectives can be defined to include, in addition to fuel, also cost, emissions, and performance aspects to solve the design problem at the system level, to find a competitive EREV configuration for the market. User-friendly methodologies are needed to help developers so that the industry at large achieves the best designs early in HEV development.

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Abbreviations

The following abbreviations are used in this manuscript:

EV	Electric vehicle
EREV	Extended range electric vehicle
APU	Auxiliary power unit
Series HEV	Series hybrid electric vehicles
RE	Range extender
ICEV	Internal combustion engine vehicle
SOC	State of charge
PHEV	Plug-in hybrid electric vehicle
FWD	Forward wheel drive
RWD	Rear-wheel drive
AWD	All wheel drive
ICE	Internal combustion engine
ICE-ER	Internal combustion engine extended range
RSA-ER	Regenerative shock absorber extended range
RB-ER	Regenerative braking extended range
RBS	Regenerative braking system
RRBCS	Revised regenerative braking control strategy
AMT	Automatic mechanical transmission
FC	Fuel cell
FC-ER	Fuel cell extended range
MGT	Micro gas turbine
MGT-ER	Micro gas turbine extended range
TAE	Thermoacoustic engine
TAE-ER	Thermoacoustic engine extended range
TAC	Thermoacoustic converter
FES	Flywheel energy storage
FES-ER	Flywheel energy storage extended range
PVC	Photovoltaic cell
SES	Solar energy storage
RE	Rotary engine
RE-ER	Rotary engine extended range
WT	Wind turbine
WT-ER	Wind turbine extended range
GHG	Greenhouse gases
EMS	Energy management system
BMS	Battery management system
OEM	Original equipment manufacturer
CAGR	Compound annual growth rate

References

1. İnci, M.; Büyük, M.; Demir, M.H.; İlbey, G. A review and research on fuel cell electric vehicles: Topologies, power electronic converters, energy management methods, technical challenges, marketing and future aspects. *Renew. Sustain. Energy Rev.* **2021**, *137*, 110648. [CrossRef]
2. Lou, G.; Ma, H.; Fan, T.; Chan, H.K. Impact of the dual-credit policy on improvements in fuel economy and the production of internal combustion engine vehicles. *Resour. Conserv. Recycl.* **2020**, *156*, 104712. [CrossRef]
3. Song, W.; Zhang, X.; Tian, Y.; Xi, L.h. A charging management-based intelligent control strategy for extended-range electric vehicles. *J. Zhejiang Univ. Sci. A* **2016**, *17*, 903–910. [CrossRef]
4. Tate, E.D.; Harpster, M.O.; Savagian, P.J. The Electrification of the Automobile: From Conventional Hybrid, to Plug-in Hybrids, to Extended-Range Electric Vehicles. *SAE Int. J. Passeng. Cars-Electron. Electr. Syst.* **2008**, *1*, 2008-01-0458. [CrossRef]
5. Song, K.; Zhang, J.; Zhang, T. Design and Development of a pluggable PEMFC extended Range Electric Vehicle. In Proceedings of the 2011 Second International Conference on Mechanic Automation and Control Engineering, Inner Mongolia, China, 15–17 July 2011; pp. 1144–1147. [CrossRef]
6. Xian, T.F.; Soon, C.M.; Rajoo, S.; Romagnoli, A. A parametric study: The impact of components sizing on range extended electric vehicle's driving range. In Proceedings of the 2016 Asian Conference on Energy, Power and Transportation Electrification (ACEPT), Singapore, 25–27 October 2016; pp. 1–6. [CrossRef]

7. Wahono, B.; Nur, A.; Santoso, W.B.; Praptijanto, A. A comparison study of range-extended engines for electric vehicle based on vehicle simulator. *J. Mech. Eng. Sci.* **2016**, *10*, 1803–1816. [CrossRef]
8. Wang, X.; Lv, H.; Sun, Q.; Mi, Y.; Gao, P. A Proportional Resonant Control Strategy for Efficiency Improvement in Extended Range Electric Vehicles. *Energies* **2017**, *10*, 204. [CrossRef]
9. Lee, W.; Jeoung, H.; Park, D.; Kim, N. An Adaptive Concept of PMP-Based Control for Saving Operating Costs of Extended-Range Electric Vehicles. *IEEE Trans. Veh. Technol.* **2019**, *68*, 11505–11512. [CrossRef]
10. Tang, T.Q.; Chen, L.; Yang, S.C.; Shang, H.Y. An extended car-following model with consideration of the electric vehicle's driving range. *Phys. A Stat. Mech. Appl.* **2015**, *430*, 148–155. [CrossRef]
11. Xu, X.; Lv, M.; Chen, Z.; Ji, W.; Gao, R. Analysis of electric vehicle extended range misalignment based on rigid-flexible dynamics. *IOP Conf. Ser. Earth Environ. Sci.* **2017**, *61*, 012018. [CrossRef]
12. Hall, J.; Marlok, H.; Bassett, M.; Warth, M. Analysis of Real World Data from a Range Extended Electric Vehicle Demonstrator. *SAE Int. J. Altern. Powertrains* **2014**, *4*, 2887. [CrossRef]
13. Dost, P.; Spichartz, P.; Sourkounis, C. Charging behaviour of users utilising battery electric vehicles and extended range electric vehicles within the scope of a field test. In Proceedings of the 2015 International Conference on Renewable Energy Research and Applications (ICRERA), Palermo, Italy, 22–25 November 2015; Volume 54, pp. 1162–1167. [CrossRef]
14. Figueroa-García, J.; López-Santana, E.; Villa-Ramírez, J.; Ferro-Escobar, R. Applied Computer Sciences in Engineering. *Commun. Comput. Inf. Sci.* **2017**, *742*, 65–71. [CrossRef]
15. Du, J.; Chen, J.; Song, Z.; Gao, M.; Ouyang, M. Design method of a power management strategy for variable battery capacities range-extended electric vehicles to improve energy efficiency and cost-effectiveness. *Energy* **2017**, *121*, 32–42. [CrossRef]
16. Guan, J.C.; Chen, B.C.; Wu, Y.Y. Design of an Adaptive Power Management Strategy for Range Extended Electric Vehicles. *Energies* **2019**, *12*, 1610. [CrossRef]
17. Shi, L.; Guo, Y.; Xiao, D.; Han, Z.; Zhou, X. Design, optimization, and study of a rare-earth permanent-magnet generator with new consequent-pole rotor for extended-range electric vehicle. *IEEJ Trans. Electr. Electron. Eng.* **2019**, *14*, 917–923. [CrossRef]
18. Du, J.; Chen, J.; Gao, M.; Wang, J. Energy Efficiency Oriented Design Method of Power Management Strategy for Range-Extended Electric Vehicles. *Math. Probl. Eng.* **2016**, *2016*, 1–9. [CrossRef]
19. Sneha Angeline, P.; Newlin Rajkumar, M. Evolution of electric vehicle and its future scope. *Mater. Today Proc.* **2020**, *33*, 3930–3936. [CrossRef]
20. Lijewski, P.; Kozak, M.; Fuć, P.; Rymaniak, Ł.; Ziółkowski, A. Exhaust emissions generated under actual operating conditions from a hybrid vehicle and an electric one fitted with a range extender. *Transp. Res. Part D Transp. Environ.* **2020**, *78*, 102183. [CrossRef]
21. Guo, R.; Cao, C.; Mi, Y.; Huang, Y. Experimental investigation of the noise, vibration and harshness performances of a range-extended electric vehicle. *Proc. Inst. Mech. Eng. Part D J. Automob. Eng.* **2016**, *230*, 650–663. [CrossRef]
22. Ramotar, L.; Rohrauer, G.L.; Filion, R.; MacDonald, K. Experimental verification of a thermal equivalent circuit dynamic model on an extended range electric vehicle battery pack. *J. Power Sources* **2017**, *343*, 383–394. [CrossRef]
23. Vatanparvar, K.; Faezi, S.; Burago, I.; Levorato, M.; Al Faruque, M.A. Extended Range Electric Vehicle with Driving Behavior Estimation in Energy Management. *IEEE Trans. Smart Grid* **2019**, *10*, 2959–2968. [CrossRef]
24. Yan, X.; Fleming, J.; Lot, R. Extending the range of Plug-in Hybrid Electric Vehicles by CVT transmission optimal management. *Energy Procedia* **2018**, *151*, 17–22. [CrossRef]
25. Kim, T.Y.; Lee, S.H. Combustion and emission characteristics of wood pyrolysis oil-butanol blended fuels in a DI diesel engine. *Int. J. Automot. Technol.* **2015**, *16*, 903–912. [CrossRef]
26. Wu, D.; Feng, L. On-Off Control of Range Extender in Extended-Range Electric Vehicle using Bird Swarm Intelligence. *Electronics* **2019**, *8*, 1223. [CrossRef]
27. Lee, G.S.; Kim, D.H.; Han, J.H.; Hwang, M.H.; Cha, H.R. Optimal Operating Point Determination Method Design for Range-Extended Electric Vehicles Based on Real Driving Tests. *Energies* **2019**, *12*, 845. [CrossRef]
28. Liu, H.; Lei, Y.; Fu, Y.; Li, X. Parameter matching and optimization for power system of range-extended electric vehicle based on requirements. *Proc. Inst. Mech. Eng. Part D J. Automob. Eng.* **2020**, *234*, 3316–3328. [CrossRef]
29. Jiang, Y. Parameters Optimization for Extended-range Electric Vehicle Based on Improved Chaotic Particle Swarm Optimization. *Int. J. Grid Distrib. Comput.* **2016**, *9*, 1–10. [CrossRef]
30. Kopczyński, A.; Krawczyk, P.; Lasocki, J. Parameters selection of extended-range electric vehicle supplied with alternative fuel. *E3S Web Conf.* **2018**, *44*, 00073. [CrossRef]
31. Ren, G.; Shan, S.; Ma, G.; Shang, X.; Zhu, S.; Zhang, Q.; Yang, T. Review of energy storage technologies for extended range electric vehicle. *J. Appl. Sci. Eng.* **2019**, *22*, 69–82. [CrossRef]
32. Baek, D.; Chang, N. Runtime Power Management of Battery Electric Vehicles for Extended Range With Consideration of Driving Time. *IEEE Trans. Very Large Scale Integr. (VLSI) Syst.* **2019**, *27*, 549–559. [CrossRef]
33. Zhao, J.b.; Han, B.y.; Bei, S.y. Start-Stop Moment Optimization of Range Extender and Control Strategy Design for Extended -Range Electric Vehicle. *IOP Conf. Ser. Mater. Sci. Eng.* **2017**, *241*, 012025. [CrossRef]
34. Li, J.; Wang, Y.; Chen, J.; Zhang, X. Study on energy management strategy and dynamic modeling for auxiliary power units in range-extended electric vehicles. *Appl. Energy* **2017**, *194*, 363–375. [CrossRef]
35. Chambon, P.; Curran, S.; Huff, S.; Love, L.; Post, B.; Wagner, R.; Jackson, R.; Green, J. Development of a range-extended electric vehicle powertrain for an integrated energy systems research printed utility vehicle. *Appl. Energy* **2017**, *191*, 99–110. [CrossRef]

36. Pozzato, G.; Formentin, S.; Panzani, G.; Savaresi, S. Least Costly Energy Management for Extended-Range Electric Vehicles with Noise Emissions Characterization. *IFAC-PapersOnLine* **2019**, *52*, 586–591. [CrossRef]
37. Pozzato, G.; Formentin, S.; Panzani, G.; Savaresi, S.M. Least costly energy management for extended-range electric vehicles: An economic optimization framework. *Eur. J. Control* **2020**, *56*, 218–230. [CrossRef]
38. Zhang, Z.; Zhang, X.; Chen, W.; Rasim, Y.; Salman, W.; Pan, H.; Yuan, Y.; Wang, C. A high-efficiency energy regenerative shock absorber using supercapacitors for renewable energy applications in range extended electric vehicle. *Appl. Energy* **2016**, *178*, 177–188; Corrigendum in **2019**, *254*, 113634. [CrossRef]
39. Satpute, N.V.; Singh, S.; Sawant, S.M. Energy Harvesting Shock Absorber with Electromagnetic and Fluid Damping. *Adv. Mech. Eng.* **2015**, *6*, 693592–693592. [CrossRef]
40. Zhang, Y.; Zhang, X.; Zhan, M.; Guo, K.; Zhao, F.; Liu, Z. Study on a novel hydraulic pumping regenerative suspension for vehicles. *J. Frankl. Inst.* **2015**, *352*, 485–499. [CrossRef]
41. Qiu, C.; Wang, G.; Meng, M.; Shen, Y. A novel control strategy of regenerative braking system for electric vehicles under safety critical driving situations. *Energy* **2018**, *149*, 329–340. [CrossRef]
42. Liu, H.; Lei, Y.; Fu, Y.; Li, X. An Optimal Slip Ratio-Based Revised Regenerative Braking Control Strategy of Range-Extended Electric Vehicle. *Energies* **2020**, *13*, 1526. [CrossRef]
43. Zhao, X.; Xu, S.; Ye, Y.; Yu, M.; Wang, G. Composite braking AMT shift strategy for extended-range heavy commercial electric vehicle based on LHMM/ANFIS braking intention identification. *Clust. Comput.* **2019**, *22*, 8513–8528. [CrossRef]
44. Aygen, M.S.; İnci, M. Zero-sequence current injection based power flow control strategy for grid inverter interfaced renewable energy systems. *Energy Sources Part Recover. Util. Environ. Eff.* **2020**, 1–22. [CrossRef]
45. Ozden, A.; Shahgaldi, S.; Li, X.; Hamdullahpur, F. A review of gas diffusion layers for proton exchange membrane fuel cells—With a focus on characteristics, characterization techniques, materials and designs. *Prog. Energy Combust. Sci.* **2019**, *74*, 50–102. [CrossRef]
46. İnci, M. Active/reactive energy control scheme for grid-connected fuel cell system with local inductive loads. *Energy* **2020**, *197*, 117191. [CrossRef]
47. Zhou, Y.; Li, H.; Ravey, A.; Péra, M.C. An integrated predictive energy management for light-duty range-extended plug-in fuel cell electric vehicle. *J. Power Sources* **2020**, *451*, 227780. [CrossRef]
48. Chu, Y.; Wu, Y.; Chen, J.; Zheng, S.; Wang, Z. Design of energy and materials for ammonia-based extended-range electric vehicles. *Energy Procedia* **2019**, *158*, 3064–3069. [CrossRef]
49. Dimitrova, Z.; Maréchal, F. Environomic design for electric vehicles with an integrated solid oxide fuel cell (SOFC) unit as a range extender. *Renew. Energy* **2017**, *112*, 124–142. [CrossRef]
50. Wu, X.L.; Xu, Y.W.; Zhao, D.q.; Zhong, X.B.; Li, D.; Jiang, J.; Deng, Z.; Fu, X.; Li, X. Extended-range electric vehicle-oriented thermoelectric surge control of a solid oxide fuel cell system. *Appl. Energy* **2020**, *263*, 114628. [CrossRef]
51. Karaoğlan, M.U.; Kuralay, N.S.; Colpan, C.O. Investigation of the effects of battery types and power management algorithms on drive cycle simulation for a range-extended electric vehicle powertrain. *Int. J. Green Energy* **2019**, *16*, 1–11. [CrossRef]
52. Liu, Y.; Li, J.; Chen, Z.; Qin, D.; Zhang, Y. Research on a multi-objective hierarchical prediction energy management strategy for range extended fuel cell vehicles. *J. Power Sources* **2019**, *429*, 55–66. [CrossRef]
53. Geng, C.; Jin, X.; Zhang, X. Simulation research on a novel control strategy for fuel cell extended-range vehicles. *Int. J. Hydrogen Energy* **2019**, *44*, 408–420. [CrossRef]
54. Almasi, A. Bright future of micro-turbines: Nuclear emergency cooling and miniature generator. *Aust. J. Mech. Eng.* **2013**, *11*, 169–175. [CrossRef]
55. Karvountzis-Kontakiotis, A.; Andwari, A.M.; Pesyridis, A.; Russo, S.; Tuccillo, R.; Esfahanian, V. Application of Micro Gas Turbine in Range-Extended Electric Vehicles. *Energy* **2018**, *147*, 351–361. [CrossRef]
56. Bou Nader, W.S.; Mansour, C.J.; Nemer, M.G. Optimization of a Brayton external combustion gas-turbine system for extended range electric vehicles. *Energy* **2018**, *150*, 745–758. [CrossRef]
57. Reine, A.; Bou Nader, W. Fuel consumption potential of different external combustion gas-turbine thermodynamic configurations for extended range electric vehicles. *Energy* **2019**, *175*, 900–913. [CrossRef]
58. Sahoo, D.; Kotrba, A.; Steiner, T.; Swift, G. Waste Heat Recovery for Light-Duty Truck Application Using ThermoAcoustic Converter Technology. *SAE Int. J. Engines* **2017**, *10*, 0153. [CrossRef]
59. Nader, W.B.; Chamoun, J.; Dumand, C. Optimization of the thermodynamic configurations of a thermoacoustic engine auxiliary power unit for range extended hybrid electric vehicles. *Energy* **2020**, *195*. [CrossRef]
60. Bou Nader, W.; Chamoun, J.; Dumand, C. Thermoacoustic engine as waste heat recovery system on extended range hybrid electric vehicles. *Energy Convers. Manag.* **2020**, *215*, 112912. [CrossRef]
61. Arani, A.K.; Karami, H.; Gharehpetian, G.; Hejazi, M. Review of Flywheel Energy Storage Systems structures and applications in power systems and microgrids. *Renew. Sustain. Energy Rev.* **2017**, *69*, 9–18. [CrossRef]
62. Itani, K.; De Bernardinis, A.; Khatir, Z.; Jammal, A. Comparative analysis of two hybrid energy storage systems used in a two front wheel driven electric vehicle during extreme start-up and regenerative braking operations. *Energy Convers. Manag.* **2017**, *144*, 69–87. [CrossRef]
63. ElNozahy, M.; Salama, M. Studying the feasibility of charging plug-in hybrid electric vehicles using photovoltaic electricity in residential distribution systems. *Electr. Power Syst. Res.* **2014**, *110*, 133–143. [CrossRef]

64. Keshri, R.; Bertoluzzo, M.; Buja, G. Integration of a Photovoltaic Panel with an Electric City Car. *Electr. Power Compon. Syst.* **2014**, *42*, 481–495. [CrossRef]
65. Ezzat, M.; Dincer, I. Development, analysis and assessment of a fuel cell and solar photovoltaic system powered vehicle. *Energy Convers. Manag.* **2016**, *129*, 284–292. [CrossRef]
66. Zahir Hussain, M.; Anbalagan, R.; Jayabalakrishnan, D.; Naga Muruga, D.; Prabhahar, M.; Bhaskar, K.; Sendilvelan, S. Charging of car battery in electric vehicle by using wind energy. *Mater. Today Proc.* **2020**. [CrossRef]
67. King, P. The Development of the Szorenyi Four-Chamber Rotary Engine. In Proceedings of the SAE International Powertrains, Fuels and Lubricants Meeting, Heidelberg, Germany, 17–19 September 2018. [CrossRef]
68. Zambalov, S.D.; Yakovlev, I.A.; Maznoy, A.S. Effect of multiple fuel injection strategies on mixture formation and combustion in a hydrogen-fueled rotary range extender for battery electric vehicles. *Energy Convers. Manag.* **2020**, *220*, 113097. [CrossRef]
69. Ferdous, S.; Bin Khaled, W.; Ahmed, B.; Salehin, S.; Ghani Ovy, E. Electric Vehicle with Charging Facility in Motion using Wind Energy. In Proceedings of the World Renewable Energy Congress, Linköping, Sweden, 8–13 May 2011; Volume 57, pp. 3629–3636. [CrossRef]
70. Goushcha, O.; Felicissimo, R.; Danesh-Yazdi, A.H.; Andreopoulos, Y. Exploring harnessing wind power in moving reference frames with application to vehicles. *Adv. Mech. Eng.* **2019**, *11*, 168781401986568. [CrossRef]
71. Hossain, M.F.; Fara, N. Integration of wind into running vehicles to meet its total energy demand. *Energy Ecol. Environ.* **2017**, *2*, 35–48. [CrossRef]
72. General Motors. 2019 Chevrolet Volt Brochure. Available online: https://www.chevrolet.ca/content/dam/chevrolet/na/canada/english/index/download-a-brochure/02-pdfs/my19-cdn-volt-brochure-en.pdf (accessed on 1 December 2020).
73. BMW. BMW i3s REX Sport 2020. Available online: https://www.guideautoweb.com/en/makes/bmw/i3/2020/specifications/s-rex/ (accessed on 1 December 2020).
74. BMW i3 (94 Ah) REX Dynamic Eléctrico 2017. Available online: https://www.bmw.com.mx/content/dam/bmw/marketMX/bmw_com_mx/Descargas/Fichas-Tecnicas-2018/i3/FichaTécnicaBMWi3(94Ah)REXDynamic2017.pdf (accessed on 1 December 2020).
75. Leach, F.; Kalghatgi, G.; Stone, R.; Miles, P. The scope for improving the efficiency and environmental impact of internal combustion engines. *Transp. Eng.* **2020**, *1*, 100005. [CrossRef]
76. Menzel, G.; Hennings Och, S.; Cocco Mariani, V.; Mauro Moura, L.; Domingues, E. Multi-objective optimization of the volumetric and thermal efficiencies applied to a multi-cylinder internal combustion engine. *Energy Convers. Manag.* **2020**, *216*, 112930. [CrossRef]
77. Ouyang, T.; Zhao, Z.; Wang, Z.; Zhang, M.; Liu, B. A high-efficiency scheme for waste heat harvesting of solid oxide fuel cell integrated homogeneous charge compression ignition engine. *Energy* **2021**, *229*, 120720. [CrossRef]
78. Hahn, S.; Braun, J.; Kemmer, H.; Reuss, H.C. Optimization of the efficiency and degradation rate of an automotive fuel cell system. *Int. J. Hydrogen Energy* **2021**. [CrossRef]
79. Hoeflinger, J.; Hofmann, P. Air mass flow and pressure optimisation of a PEM fuel cell range extender system. *Int. J. Hydrogen Energy* **2020**, *45*, 29246–29258. [CrossRef]
80. Toyota. Second Generation Toyota Mirai. Still Zero Emissions. Available online: https://www.toyota-europe.com/world-of-toyota/articles-news-events/2019/new-mirai-concept (accessed on 1 December 2020).
81. Hyundai NEXO de pila de combustible | Hyundai | Hyundai Motor España. Available online: https://www.hyundai.com/es/modelos/nexo.html (accessed on 1 December 2020).
82. Nikola Two. Available online: https://nikolamotor.com/two (accessed on 1 December 2020)
83. Taner, T. The novel and innovative design with using H_2 fuel of PEM fuel cell: Efficiency of thermodynamic analyze. *Fuel* **2021**, *302*, 121109. [CrossRef]
84. Ji, C.; Wang, H.; Shi, C.; Wang, S.; Yang, J. Multi-objective optimization of operating parameters for a gasoline Wankel rotary engine by hydrogen enrichment. *Energy Convers. Manag.* **2021**, *229*, 113732. [CrossRef]
85. Sadiq, G.A.; Al-Dadah, R.; Mahmoud, S. Development of rotary Wankel devices for hybrid automotive applications. *Energy Convers. Manag.* **2019**, *202*, 112159. [CrossRef]
86. Mazda 2 RE Range-Extender: Return of the Rotary-News-Car and Driver. Available online: https://www.caranddriver.com/news/a15366035/mazda-2-re-range-extender-return-of-the-rotary/ (accessed on 1 November 2020).
87. Martins, J.J.; Uzuneanu, K.; Ribeiro, B.S.; Jasasky, O. Thermodynamic Analysis of an Over-Expanded Engine. *SAE Tech. Pap.* **2004**, *113*, 476–490. [CrossRef]
88. Zhao, J.; Ma, Y.; Zhang, Z.; Wang, S.; Wang, S. Optimization and matching for range-extenders of electric vehicles with artificial neural network and genetic algorithm. *Energy Convers. Manag.* **2019**, *184*, 709–725. [CrossRef]
89. Zhang, J.; Li, Y.; Lv, C.; Yuan, Y. New regenerative braking control strategy for rear-driven electrified minivans. *Energy Convers. Manag.* **2014**, *82*, 135–145. [CrossRef]
90. Yang, Y.; He, Q.; Chen, Y.; Fu, C. Efficiency Optimization and Control Strategy of Regenerative Braking System with Dual Motor. *Energies* **2020**, *13*, 400–411. [CrossRef]
91. Duan, J.; Fan, S.; An, Q.; Sun, L.; Wang, G. A comparison of micro gas turbine operation modes for optimal efficiency based on a nonlinear model. *Energy* **2017**, *134*, 400–411. [CrossRef]

92. Nicolosi, F.F.; Renzi, M. Effect of the Regenerator Efficiency on the Performance of a Micro Gas Turbine Fed with Alternative Fuels. *Energy Procedia* **2018**, *148*, 687–694. [CrossRef]
93. Ezzat, M.F.; Dincer, I. Development and exergetic assessment of a new hybrid vehicle incorporating gas turbine as powering option. *Energy* **2019**, *170*, 112–119. [CrossRef]
94. Ji, F.; Zhang, X.; Du, F.; Ding, S.; Zhao, Y.; Xu, Z.; Wang, Y.; Zhou, Y. Experimental and numerical investigation on micro gas turbine as a range extender for electric vehicle. *Appl. Therm. Eng.* **2020**, *173*, 115236. [CrossRef]
95. Barakat, A.A.; Diab, J.H.; Badawi, N.S.; Bou Nader, W.S.; Mansour, C.J. Combined cycle gas turbine system optimization for extended range electric vehicles. *Energy Convers. Manag.* **2020**, *226*, 113538. [CrossRef]
96. Fathabadi, H. Utilizing solar and wind energy in plug-in hybrid electric vehicles. *Energy Convers. Manag.* **2018**, *156*, 317–328. [CrossRef]
97. Fathabadi, H. Recovering waste vibration energy of an automobile using shock absorbers included magnet moving-coil mechanism and adding to overall efficiency using wind turbine. *Energy* **2019**, *189*, 116274. [CrossRef]
98. de Dios Javier Roldán, I.C.M. Meet Eolo, A Wind-Powered EV From Colombia. Available online: https://www.iamrenew.com/green-transportation/meet-eolo-wind-powered-ev-colombia/#:~:text=The%20Eolo%2C%20Colombia's%20only%20homegrown,it%20is%20powered%20by%20wind (accessed on 1 January 2021).
99. Boyes, J.D.; Clark, N.H. Technologies for energy storage flywheels and super conducting magnetic energy storage. In Proceedings of the 2000 Power Engineering Society Summer Meeting (Cat. No. 00CH37134), Seattle, WA, USA, 16–20 July 2000; Volume 3, pp. 1548–1550. [CrossRef]
100. Li, J.; Zhao, J. Energy recovery for hybrid hydraulic excavators: Flywheel-based solutions. *Autom. Constr.* **2021**, *125*, 103648. [CrossRef]
101. Erdemir, D.; Dincer, I. Assessment of Renewable Energy-Driven and Flywheel Integrated Fast-Charging Station for Electric Buses: A Case Study. *J. Energy Storage* **2020**, *30*, 101576. [CrossRef]
102. Wang, W.; Li, Y.; Shi, M.; Song, Y. Optimization and control of battery-flywheel compound energy storage system during an electric vehicle braking. *Energy* **2021**, *226*, 120404. [CrossRef]
103. Vazquez, S.; Lukic, S.M.; Galvan, E.; Franquelo, L.G.; Carrasco, J.M. Energy storage systems for transport and grid applications. *IEEE Trans. Ind. Electron.* **2010**, *57*, 3881–3895. [CrossRef]
104. Puddu, P.; Paderi, M. Hydro-pneumatic accumulators for vehicles kinetic energy storage: Influence of gas compressibility and thermal losses on storage capability. *Energy* **2013**, *57*, 326–335. [CrossRef]
105. Chen, B.; Yousif, A.A.; Riley, P.H.; Hann, D.B. Development and Assessment of Thermoacoustic Generators Operating by Waste Heat from Cooking Stove. *Engineering* **2012**, *04*, 894–902. [CrossRef]
106. Backhaus, S.; Swift, G.W. A thermoacoustic-Stirling heat engine: Detailed study. *J. Acoust. Soc. Am.* **2000**, *107*, 3148–3166. [CrossRef]
107. Mumith, J.A.; Makatsoris, C.; Karayiannis, T.G. Design of a thermoacoustic heat engine for low temperature waste heat recovery in food manufacturing: A thermoacoustic device for heat recovery. *Appl. Therm. Eng.* **2014**, *65*, 588–596. [CrossRef]
108. Blanc-benon, P.; Jondeau, E.; Comte-Bellot, G. Analysis of the acoustic field in a thermoacoustic system using time-resolved particle image velocimetry and constant-voltage anemometry. In Proceedings of the 3rd International Workshop on Thermoacoustics, Enschede, The Netherlands, 26–27 October 2015.
109. Khoshnoud, F.; Zhang, Y.; Shimura, R.; Shahba, A.; Jin, G.; Pissanidis, G.; Chen, Y.K.; De Silva, C.W. Energy Regeneration from Suspension Dynamic Modes and Self-Powered Actuation. *IEEE/ASME Trans. Mechatron.* **2015**, *20*, 2513–2524. [CrossRef]
110. Li, Z.; Zuo, L.; Luhrs, G.; Lin, L.; Qin, Y.X. Electromagnetic energy-harvesting shock absorbers: Design, modeling, and road tests. *IEEE Trans. Veh. Technol.* **2013**, *62*, 1065–1074. [CrossRef]
111. Maravandi, A.; Moallem, M. Regenerative shock absorber using a two-leg motion conversion mechanism. *IEEE/ASME Trans. Mechatron.* **2015**, *20*, 2853–2861. [CrossRef]
112. Electric Vehicle Range Extender Market Forecast Report, 2018–2025. Available online: https://www.marketsandmarkets.com/Market-Reports/electric-vehicle-range-extender-market-208131566.html (accessed on 1 July 2021).
113. Electric Vehicle (EV) Range Extender Market Statistics, Trends, Demand, Size by 2026. Available online: https://www.alliedmarketresearch.com/electric-vehicle-range-extender-market-A06026 (accessed on 1 July 2021).
114. Electric Vehicle Range Extender Market to Witness 10.2% CAGR By 2025 Owing to Rising Usage of Commercial & Fully Electric Passenger Vehicles to Lower CO_2 Emissions | Million Insights. Available online: https://www.prnewswire.com/news-releases/electric-vehicle-range-extender-market-to-witness-10-2-cagr-by-2025-owing-to-rising-usage-of-commercial--fully-electric-passenger-vehicles-to-lower-co2-emissions--million-insights-301220939.html (accessed on 1 July 2021).
115. 2021 Honda Clarity Plug-In Hybrid—The Versatile Hybrid | Honda. Available online: https://automobiles.honda.com/clarity-plug-in-hybrid (accessed on 1 July 2021).
116. Mack Trucks to Evaluate Wrightspeed Route Powertrain in Mack LR Model | Mack Trucks. Available online: https://www.macktrucks.com/mack-news/2016/mack-trucks-to-evaluate-wrightspeed-route-powertrain-in-mack-lr-model/ (accessed on 1 July 2021).
117. Rover, L. Quarterly Light-Vehicle—Q1 2021. 2021. Available online: https://www.coxautoinc.com/wp-content/uploads/2021/04/Q1.Kelley-Blue-Book-Electrfication-Deck-2021.revised-4.26.pdf (accessed on 1 July 2021).
118. Sales, Q.; Ev, B. Electrified-Vehicle 2021. pp. 1–5. Available online: https://www.coxautoinc.com/wp-content/uploads/2021/01/Kelley-Blue-Book-Salesand-Data-Report-for-2020-Q4.pdf (accessed on 1 July 2021).

119. Masclans Abelló, P.; Medina Iglesias, V.; de los Santos López, M.A.; Álvarez-Flórez, J. Real drive cycles analysis by ordered power methodology applied to fuel consumption, CO_2, NO_x and PM emissions estimation. *Front. Environ. Sci. Eng.* **2021**, *15*, 4. [CrossRef]
120. Lee, D.; Park, G.; Son, B.; Jung, H. Efficiency improvement of IPMSG in the electric power generating system of a range-extended electric vehicle. *IET Electr. Power Appl.* **2019**, *13*, 943–950. [CrossRef]
121. Han, K.; Nguyen, T.W.; Nam, K. Battery energy management of autonomous electric vehicles using computationally inexpensive model predictive control. *Electronics* **2020**, *9*, 1277. [CrossRef]
122. Hu, X.; Zhang, X.; Tang, X.; Lin, X. Model predictive control of hybrid electric vehicles for fuel economy, emission reductions, and inter-vehicle safety in car-following scenarios. *Energy* **2020**, *196*, 117101. [CrossRef]
123. Fathy, H.; Reyer, J.; Papalambros, P.; Ulsov, A. On the coupling between the plant and controller optimization problems. In Proceedings of the 2001 American Control Conference. (Cat. No.01CH37148), Arlington, VA, USA, 25–27 June 2001; Volume 3, pp. 1864–1869. [CrossRef]
124. Silvas, E.; Hofman, T.; Murgovski, N.; Etman, P.; Steinbuch, M. Review of Optimization Strategies for System-Level Design in Hybrid Electric Vehicles. *IEEE Trans. Veh. Technol.* **2016**, *66*. [CrossRef]
125. Allison, J.T.; Herber, D.R. Special Section on Multidisciplinary Design Optimization: Multidisciplinary Design Optimization of Dynamic Engineering Systems. *AIAA J.* **2014**, *52*, 691–710. [CrossRef]