The Full-Hybrid Powertrain of the new BMW ActiveHybrid 5

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Summary

Mit dem ActiveHybrid X6 und dem ActiveHybrid 7 hat BMW bereits zwei Hybrid-Modelle erfolgreich auf den Markt gebracht. Im Rahmen der Efficient Dynamics Strategie verfolgt die BMW Group den Weg konsequent weiter, über die Einführung der Hybrid-Technologie in weitere Fahrzeugbaureihen die CO_2 Emissionen der Fahrzeugflotte nachhaltig zu reduzieren. Der nächste Schritt steht nun in der oberen Mittelklasse mit der Serieneinführung des BMW ActiveHybrid 5 unmittelbar bevor.

Wesentliche Zielsetzungen für den Antrieb waren eine signifikante und kundenwerte Verbrauchsreduzierung, eine markenadäquate Ausprägung des elektrischen Fahrerlebnisses, sowie eine intelligente Vernetzung der Fahrzeugsysteme zur optimalen Anpassung der Betriebsstrategie an die Fahrsituation. Mit dem gewählten Konzept sowie den durch eine gezielte Neuentwickung elektrischer Antriebskomponenten realisierbaren neuen Antriebsfunktionen konnten diese Anforderungen in beeindruckender Weise erfüllt werden. Dabei ist ein Fahrzeug entstanden, das die BMW-typische Fahrdynamik und Agilität mit höchster Effizienz vereint.

With the ActiveHybrid X6 and the ActiveHybrid 7, BMW has already successfully launched two hybrid vehicles. Within the context of the Efficient Dynamics strategy, the BMW Group consequently follows the way of sustainable reduction of CO_2 emissions of the vehicle fleet by introducing the hybrid technology in further vehicle product lines. With the launch of the series production of the BMW ActiveHybrid 5, the next step is now directly ahead in the upper middle class.

Essential targets for the powertrain were a significant and customer-relevant reduction of the fuel consumption, an electric driving experience appropriate for the BMW brand, as well as the intelligent combination of vehicle systems in order to optimally adjust the operating strategy to the driving situation. With the selected concept and the newly developed electric components and powertrain functions, these requirements have been met in an impressive way. By this, a vehicle has been created which combines BMW-like driving dynamics with highest efficiency.

1 Introduction

In the development of highly efficient powertrains, the new powertrain of the ActiveHybrid 5 represents another consistent step in the Efficient Dynamics strategy of the BMW Group.

Today the customer can choose from various hybrid cars from different manufacturers. The different concepts mean the customer faces a difficult task in deciding what powertrain system is the right one for his individual requirements. As a manufacturer it was necessary for BMW to realise a concept that on the one hand exhausts the maximum fuel economy potential of the hybrid technology and on the other offers the powertrain characteristics and drivability typical of BMW also in electrified powertrains.

The well-known 6-cylinder N55 with the 8-speed automatic transmission is the basis of the ActiveHybrid 5. The aim was to make all necessary adaptations in this well-known package for integration of the electric motor. Based on the ActiveHybrid 7 [1] and the ActiveHybrid X6 [2] the challenge in the development of the parallel hybrid lays in implementing an operating strategy which enables efficient use of the electrical energy in line with the electrical driving experience.

In addition, the important core components of the new powertrain system have been developed from scratch and designed to the requirements of a full parallel hybrid concept. The lithium-ion battery, developed and produced in-house, the power electronics and the electric motor result in an electric powertrain system which is connected via the electronics of the combustion engine to give one harmonious unit. A starter unit for the combustion engine which was developed especially for this application ensures that the full electric powertrain energy is available for electric driving under all conditions.

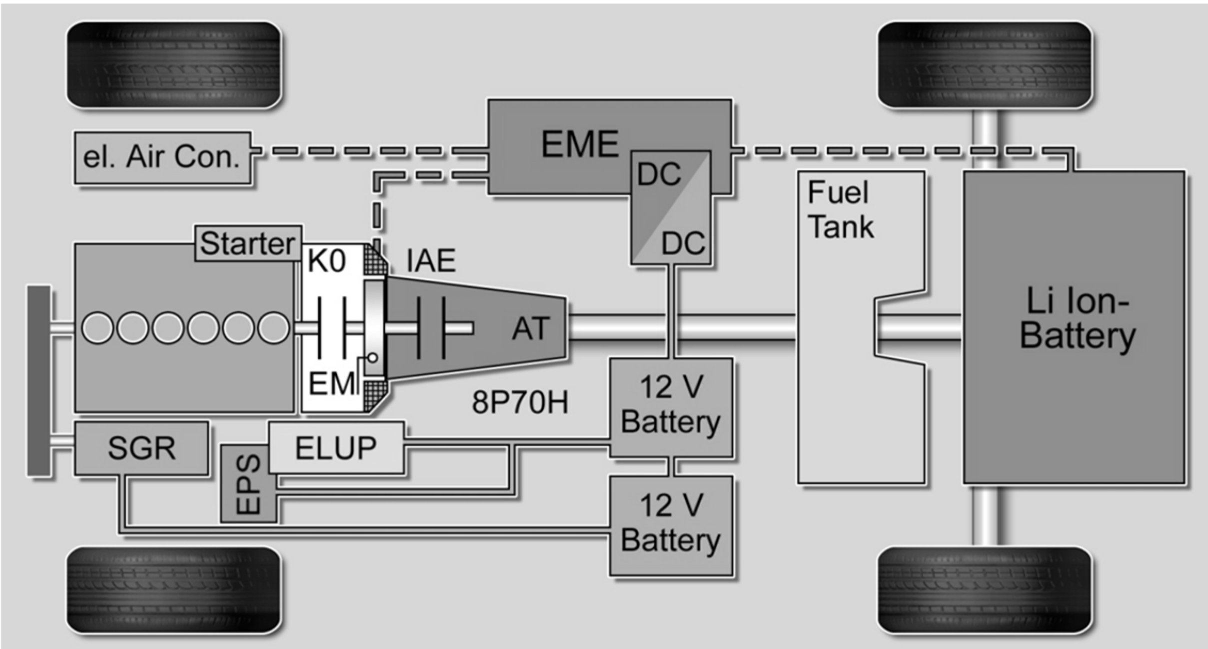
Another focal point is the intelligent networking of the two drive systems within the framework of the Connected Drive approach. Here navigation data have influence on the operating strategy and thus lead to a new dimension in the networking of systems.

2 Drive concept

The market for hybrid drives is today shaped by a variety of different concepts in diverse designs. There is a rising number of power-split concepts, parallel and serial hybrid drives on the market, or provide an outlook of future applications in the form of concept studies. Also the degree of electrification ranges from mild hybrid solutions without pure electrical drive and full hybrid applications with electrical distances of a few kilometres for inner-city speeds and accelerations to plugin hybrids with the option of managing typical distances such as the daily commute to work by pure electric drive. There is high dynamism in the development of this segment of drive technology and it is a challenge for all vehicle manufacturers to develop concepts which on the one hand optimally use the functional potential of the hybrid technology and on the other can be realized efficiently in a wide variety of applications.

A fundamental objective in the design decision was therefore to define an architecture which both satisfies current requirements and also offers excellent scalability for future designs. The requirement for high synergies with the conventional drive, as well as the preservation of the typical BMW driving experience for the hybrid application, also played a decisive role in the selection of the technical concept for the hybrid drive of the ActiveHybrid 5.

Based on these considerations, a parallel hybrid design was chosen with the capability of purely electric driving for the powertrain concept of the ActiveHybrid 5. The transmission is an 8-speed automatic, which bears high synergies with conventional transmissions. An integrated electrical machine takes the space of the conventional torque converter and the start-up function is realized by an internal transmission clutch. A separating clutch is located between the electrical machine and the combustion engine. This allows the combustion engine to be disconnected from the drive and thus makes possible purely electric driving with a stationary combustion engine. For optimal electric vehicle performance, as well as excellent comfort and response characteristics during start of the combustion engine, the design has a separate starter unit which has been integrated as an additional starter motor in the belt drive. Figure 1 illustrates the powertrain architecture of the ActiveHybrid 5.



Abbreviations:

K0: Separating clutch: combustion engine – transmission/E-machine

EM: Electric Machine

IAE:	Integrated start-up element
EME:	High-voltage power electronics with integrated control unit
DC/DC:	Voltage converter HV – 12V
SGR:	Starter unit in the belt drive
EPS:	Electric power-steering pump
ELUP:	Electric pump for brake servo

Fig. 1: Powertrain topology of the ActiveHybrid 5

3 The powertrain components of the ActiveHybrid 5

3.1 Combustion engine

The 3.0 l six-cylinder gasoline engine, which is also used in the non-hybrid vehicle 535i, is used as a combustion engine [3].

The firmly established combination of direct injection with turbocharging has been complemented in this engine for the first time with the fully variable valve train VALVETRONIC introduced by BMW and is one of the most efficient combustion engines of its kind. To achieve a high power output in the naturally aspirated region of the engine map, as well as a high turbocharged full load, and at the same time high specific performance values with direct response characteristics, the cylinder bank separation favourable with the six-cylinder has been maintained through the use of a turbocharger according to the twin-scroll principle.

The results are excellent full load values with a low-end torque of 400 Nm at an engine speed of 1200 rpm and maximum power of 225 kW at 5800 rpm in combination with outstanding response characteristics.

The modifications of the combustion engine are restricted to the adaptation of the belt drive for integration of the starter unit together with a cancellation of all other ancillary components.

3.2 Starter system

The comfort of the start of the combustion engine from electric driving is particularly important for full hybrid electric powertrains. In order to fulfil the requirements for this engine start an additional starter system has been integrated. This system comprises a 12V battery, which can be galvanically isolated from the 12V power supply battery, and a starter motor in the belt drive which has significant advantages over a conventional starter with regard to NVH quality. The starter motor is a claw-pole machine with integrated power electronics. Modifications to the belt drive ensure that the mechanical energy can be reliably transferred to the crankshaft.

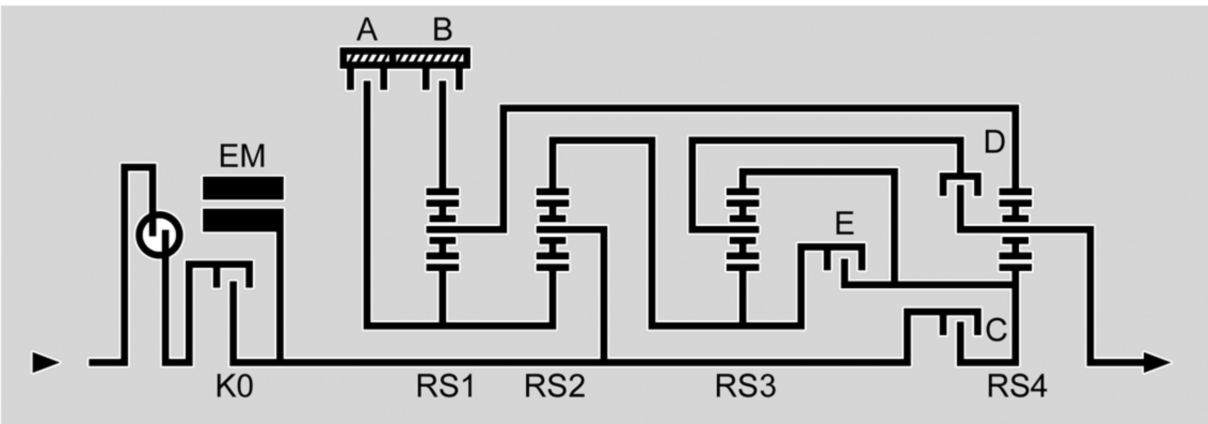
3.3 Hybrid transmission

One of the most important strategic objectives within the framework of the development of the hybridised automatic transmission for the new BMW ActiveHybrid 5 was the implementation of a modular and scalable transmission concept based on the conventional 8-speed automatic transmissions which can be used in combination with the entire BMW engine range and in all BMW vehicle product lines.

As a logical next step to the above-mentioned objective it was also necessary to integrate the hybrid-specific additional components, separating clutch and E-machine, without the requirement for any additional installation space in comparison to the conventional transmission. For this purpose a hydro-dynamic torque converter was omitted in the hybrid transmission. The free installation space arising in the transmission bell housing is instead used to install the hybrid drive comprising the E-machine (incl. water cooling shell, rotor position sensor and power connection), separating clutch and torsional vibration damper with the same spatial requirement as that required in the conventional basic transmission. The existing geometric interfaces such as motor flange, gearbox mounting, position of the oil cooler connections, position of the transmission connector, etc. are identical to the conventional version of the gearbox.

In order to support the fuel economy benefits of the hybrid technology, in the development special attention was paid to the efficiency characteristics of the hybrid-specific changes to the transmission. Care was also taken to ensure that the general energy consumption of the transmission is optimized.

The typical BMW characteristics of excellent dynamic gearshifts and precision together with excellent comfort were able to be implemented in the hybridised transmission as another fundamental contribution to the corporate strategy Efficient Dynamics. Figure 2 shows the transmission topology, as well as an overview of the fundamental characteristics of the hybrid transmission.



Development code	8P70H
Derived from standard transmission	8HP70
Max. input torque capacity	- Combustion engine 650 Nm
	- Total 700 Nm
Max. input speeds	1^{st} - 7^{th} gear: 7,200 rpm
	8^{th} gear: 5,700 rpm
Starting element	- Integrated, wet multiple disc clutch
	- Maximum stall torque 440 Nm
Space requirements	Comparable to 8HP70 (Length identical, no additional diameter requirements)
4x4 suitability	Suitable without additional installation space
Gear ratios / spread (identical to 8HP transmission family)	1^{st} gear: 4.714
	2^{nd} gear: 3.143
	3^{rd} gear: 2.106
	4^{th} gear: 1.667
	5^{th} gear: 1.285
	6^{th} gear: 1.000
	7^{th} gear: 0.839
	8^{th} gear: 0.667
	Reverse gear: - 3.317
	Ratio spread: 7.071
Hybrid functions	- Full electrical drive
	- Start, stop combustion engine at vehicle standstill and while electrical drive
	- Start at e-motor-speed of 0 rev/min
	- Brake energy recuperation
	- Coasting
Weight (incl. E-Motor and transmission fluid)	106 kg

Fig. 2: Transmission topology / Technical data

The use of the planetary gear set, clutchs, shafts, bearing and the mechanical vane-pump from the conventional 8HP basic transmission can be mentioned as key advantages for the hybrid transmission module. The electronic control unit is also a common part. The hydraulic control unit is essentially based on the concept of the basic transmission, but has been modified with the integrated start-up clutch and individual hybrid-specific extensions.

The **torsional vibration damper** was designed especially for the requirements of the hybrid vehicle with its specific operating points, and for the improvement of the acoustic decoupling of the combustion engine, it offers lower torsional stiffness in the lower load range than in the upper load range up to the full load of the combustion engine.

The **separating clutch** in the transmission is required in order to disconnect the combustion engine from the transmission input when driving in full electric mode. The element has been realised here as a closed multidisc wet clutch. By optimisation measures the drag torque of the open clutch could be lowered in favour of optimal efficiency when driving fully electrically. To improve the powertrain comfort, the separating clutch can be operated in relevant driving areas also in the so-called micro slip control similar to the torque converter clutch in the conventional transmission.

Due to the omission of a hydraulic torque converter with the hybrid transmission, the brake (B) present in the conventional transmission is designed here as an **integrated start-up element** so that the creep and start-up functions can be realized in a suitable form.

As the conventional mechanical transmission oil pump is not driven when the combustion engine is switched off and at very low vehicle speeds for energy reasons, an **additional electric oil pump** in the gear oil sump assumes the necessary hydraulic supply of the transmission in these operating points. For energy-efficiency reasons the pump is only operated at the minimum power required through an intelligent operating strategy in the respective operating point.

3.4 Electrical drive system

The electrical drive system of the BMW ActiveHybrid 5 is shown in Figure 3.

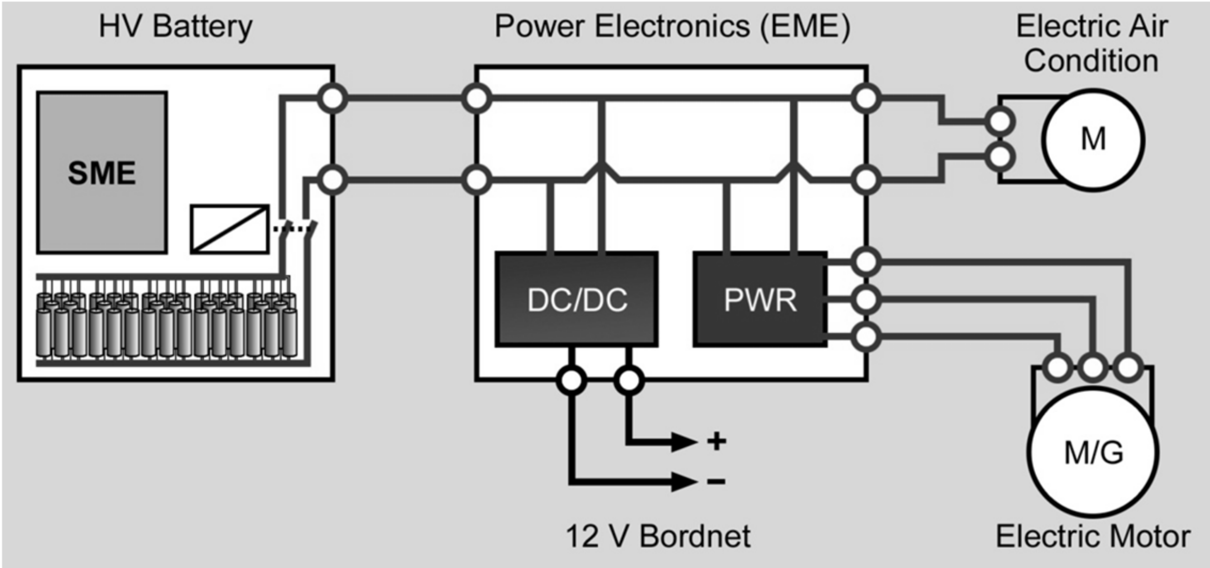


Figure 3: Circuit diagram of the electrical drive system

The power electronics is the central control unit in the electrical drive system. In addition to the energy supply of the electric A/C compressor, the power electronics contains the DC/DC converter and the pulse width modulated inverter. The liquid cooling ensures that the power electronics can maintain its functionality in all operating points and within a wide range of thermal conditions.

The **DC/DC converter** assumes the function of the conventional alternator in the vehicle and supplies the 12V vehicle electrical system with the necessary energy. Using the power electronics the HV DC voltage is converted into the vehicle voltage of the 12V supply according to the requirements. The maximum output power of the DC/DC converter is 2.4 kW permanently and 2.8 kW in peaks.

The **pulse control inverter** (PWR) controls the E-machine. Using an IGBT B6 bridge circuit it converts the HV DC voltage into a 3-phase alternating current, which controls the E-machine. The bidirectionality ensures that both the motor-driven and alternator operation can be represented.

The **E-machine** is a permanently excited synchronous machine. The rotor uses 16 pole pairs with rare-earth magnets. The stator consists of 24 coils and is, similar to the power electronics, liquid-cooled. The E-machine uses field orientated control. The electrical machine delivers a maximum power of 40 kW and a maximum torque of 210 Nm.

3.5 Lithium-ion high-voltage battery

The lithium-ion high-voltage battery, HV battery for short, in the BMW ActiveHybrid 5 is characterised by a compact and modular design, high power density and a high safety standard. It is integrated in the boot behind the rear seat bench. The fundamental characteristic values are compiled in Figure 4. It is the first HV battery which has been developed and produced directly at the BMW Group within the framework of the in-house strategy.

Producer	BMW Group	Voltage, nominal	317 V
No. of cells	96	Voltage range	200... 385 V
No. of modules	8	Capacity, nominal	4 Ah
Weight	< 46 kg	Stored energy, nominal	1,350 Wh
Volume	approx. 40 l	Max. discharge power	43 kW

Figure 4: Characteristic values of the lithium-ion high-voltage battery

The HV battery comprises 96 lithium iron phosphate cells connected in series. Every twelve cells are arranged in a compact module and welded by laser. A CSC (Cell Supervision Circuit) monitors the individual cell voltages, as well as the temperature, for each module. In addition, the cells can be balanced to the same state of charge using the CSCs. The eight CSCs are connected within the HV battery to a central control unit, the SME, via an internal CAN. The SME communicates with the vehicle via another CAN connection. It contains the battery management functions and activates the relays in the HV battery, as well as a refrigerant valve. Via the relay the cell string is disconnected from the vehicle power supply when in rest state, as well as for uncertain states. In addition, a HV fuse is integrated in the event of a short circuit.

The battery management contains, in addition to sequential control (e.g. wake-up, switching of relays), several safety functions, algorithms for state detection of the HV battery (state of charge, ageing, current performance), as well as different diagnostic functions. In combination with functions in the vehicle the battery management ensures safe operation. In the event of interferences the operation is maintained as far as possible using a degradation concept. In the event of uncertain states the HV battery is disconnected from the HV vehicle electrical system. In addition, the battery management controls the cooling of the HV battery.

The cooling is necessary as high temperatures may lead to accelerated ageing in the case of lithium-ion cells. The temperature increases both through the power loss in operation, as well as through external heat entry in the case of high ambient temperatures and solar radiation. To achieve high availability and long service life, a direct refrigerant cooling has been integrated in the HV battery of the BMW ActiveHybrid 5. The HV battery is connected directly to the vehicle air-conditioning system. In the event of a cooling requirement, liquid refrigerant is fed into the HV battery via a switchable expansion valve. Within the HV battery the refrigerant evaporates and in the process extracts the heat from the cells. The direct refrigerant cooling leads to a very compact design. In addition, it is very efficient as no additional heat exchange processes are necessary.

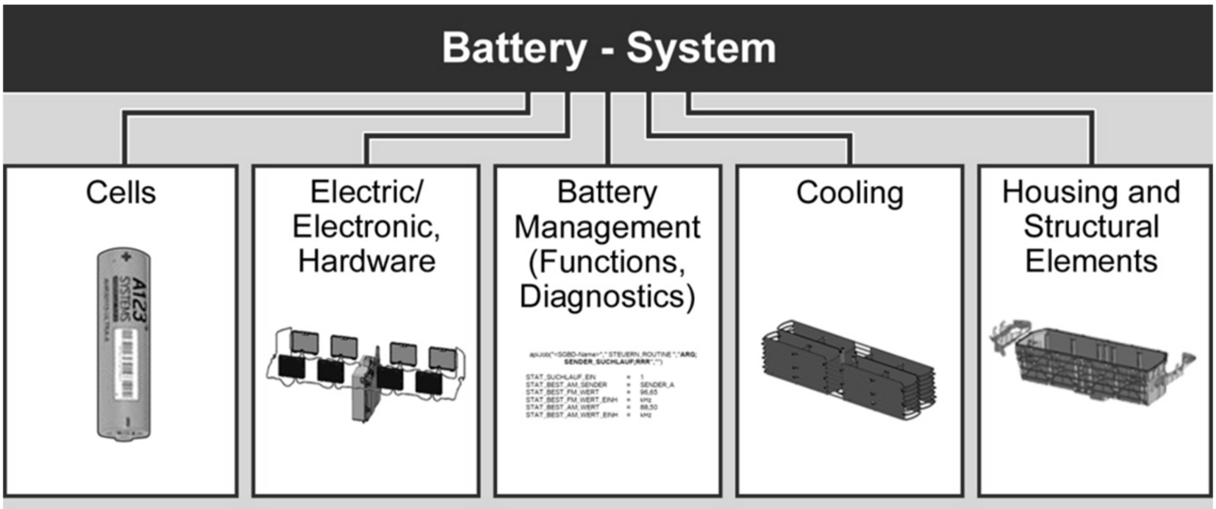


Figure 5: Lithium-ion high-voltage battery in the BMW ActiveHybrid 5

The HV battery has a stable aluminium housing. It is used for the mounting in the vehicle and as protection of the inside against mechanical damage and environmental influences. In addition, the HV battery has a three-stage safety concept, starting with a safe cell, a three-stage software concept and a sophisticated mechanical structure and intelligent vehicle integration.

4 The powertrain functions of the ActiveHybrid 5

As a full hybrid concept the ActiveHybrid 5 offers the option of purely electric and thus locally emission-free driving with a stationary combustion engine. This is possible up to a speed of max. 60 km/h. With an energy content in the HV battery of 1.35 kWh a distance of up to 3 km can be managed fully electrically.

In addition, the electrical machine is used to support the combustion engine also in running operation. This happens on the one hand in the form of a stationary electric drive torque which is superimposed with the combustion engine torque at high performance requirements (electric overboost function). On the other hand, the high dynamics of the electrical machine are used to positively support the dynamic response characteristics of the combustion engine (dynamic boost). By this, the excellent response characteristics of the turbocharged 6-cylinder engine already present in the conventional version have been increased even further. The negative influences on driving dynamics caused by the additional weight of the hybrid components have been compensated. Finally, it is also possible to implement some of the driver's torque request through an electric drive torque with a parallel reduction of the load of the combustion engine (Assist function). However, as this is associated with a reduction of the specific combustion engine efficiency, this function is used restrictively and only when there is a high supply of electrical energy.

The electrical energy required for the electrical drive functions is provided via two operating modes. During deceleration processes the electrical machine is operated as an alternator and thus kinetic energy of the vehicle is converted into electrical energy and stored in the HV battery. This happens both in coasting mode, as well as in superposition to the mechanical torque of the friction brake when braking. However, as the electrical energy requirement cannot be produced fully using this function load shifting is required as an additional operating mode. In this mode an alternator torque of the electrical machine is adjusted in the combustion engine operation, which is compensated precisely by an increase in the load point of the combustion engine to fulfil the driver's request torque. This process is of course associated with energy losses and therefore demands precise knowledge of the individual efficiency levels in the hybrid system. Nevertheless, electrical energy can also be generated efficiently via load shifting, which makes a positive contribution to the fuel economy benefits by the hybrid system.

4.1 Operating strategy

In the development of the powertrain functions of the ActiveHybrid 5, the maximization of the fuel economy benefits of the hybrid technology had the highest priority. During the design stage of the operating strategy special attention was thus paid to the detailed consideration of efficiency chains in the individual operating modes. Using intelligent control strategies, the adaptation of the operating strategy to energy flows depending on the driving profile and vehicle condition are of decisive importance in order to achieve the optimum for the partly competing requirements between maximum electric driving experience and lower fuel consumption. The operating strategy controls the hybrid functions, such as an automatic engine start-stop function, electric driving range, energy recuperation and operating point optimisation.

But also other functions such as the powertrain acoustics, emissions or performance limits under extreme ambient temperatures must be taken into consideration. In addition, it was important to achieve a system behaviour which is comprehensible by the customer, in order to enable a controlled use of the electric driving mode.

An important parameter for developing a full hybrid operating strategy and the drive character of a hybrid vehicle is the choice of the maximum electric acceleration and speed (E-driving range), above whose limits the combustion engine starts up.

In the ActiveHybrid 5 various input data such as battery state of charge, vehicle mode settings, gradient or state of the hybrid components, are prioritised intelligently on the EME control unit and the E-driving area optimal for fuel consumption and E-drive range is selected from this. This also includes the selection of the speed range (up to a max. 160 km/h) in which the combustion engine is switched off during deceleration and makes possible electric coasting.

To exhaust the full fuel economy potential an intelligent **state of charge control** is necessary. Depending on the operating point and state of the combustion engine and the electrical drive components, the cost-benefit ratio of an increase or decrease in the load point is identified. With this information the charging or discharging of the battery is ordered depending on the state of charge (SOC), as well as other factors. The efficient supply of the vehicle electrical system and the electrical A/C compressor for interior and battery cooling is thus constantly guaranteed.

The functionalities for **degradation** of the hybrid system are also implemented in the EME control unit and compiled in a degradation manager. Basically each component of the HV system (high-voltage battery, E-machine, power electronics) is protected against thermal overload by its own module protection. With the full utilization of these maximum permissible system limits, the degradation manager ensures, through controlled restriction or targeted modelling of the energy flows, operation at extreme temperatures (hot or cold conditions) at the best possible climate comfort and maximum hybrid functionality.

Navigation-based predictive operating strategy

The decision whether to activate the electric driving mode is made in the central hybrid control unit using calibrated maps. As described above, a variety of parameters are taken into consideration in this decision. Due to the alternating driving situations in a customer driving cycle, situations may occur for example where electric driving would be possible on account of speed and acceleration, but the system does not have enough electrical energy stored at the time to perform the stretch ahead using electric driving. Another case is a downhill gradient ahead, in the case of which the recuperation potential cannot be fully utilised because the HV battery is already fully charged at the start of the downhill gradient. To better adapt the system behaviour of the hybrid drive to the respective driving situation, for the first time ever information from the vehicle navigation system is integrated in the operating strategy for the ActiveHybrid 5.

If the driver enters a destination in the navigation system, the route data from the navigation control unit are sent to the EME and included in the calculation of the operating strategy. The system takes into consideration the following route information:

- Route gradient information: Before a downhill gradient the HV battery is not charged or discharge is increased via a recuperation energy forecast in order to be able to fully exploit the recuperation potential of the downhill gradient (Fig. 6). Lower fuel consumption in comparison to conventional strategies, which continuously charge the battery to a high target SOC, is thus achieved.

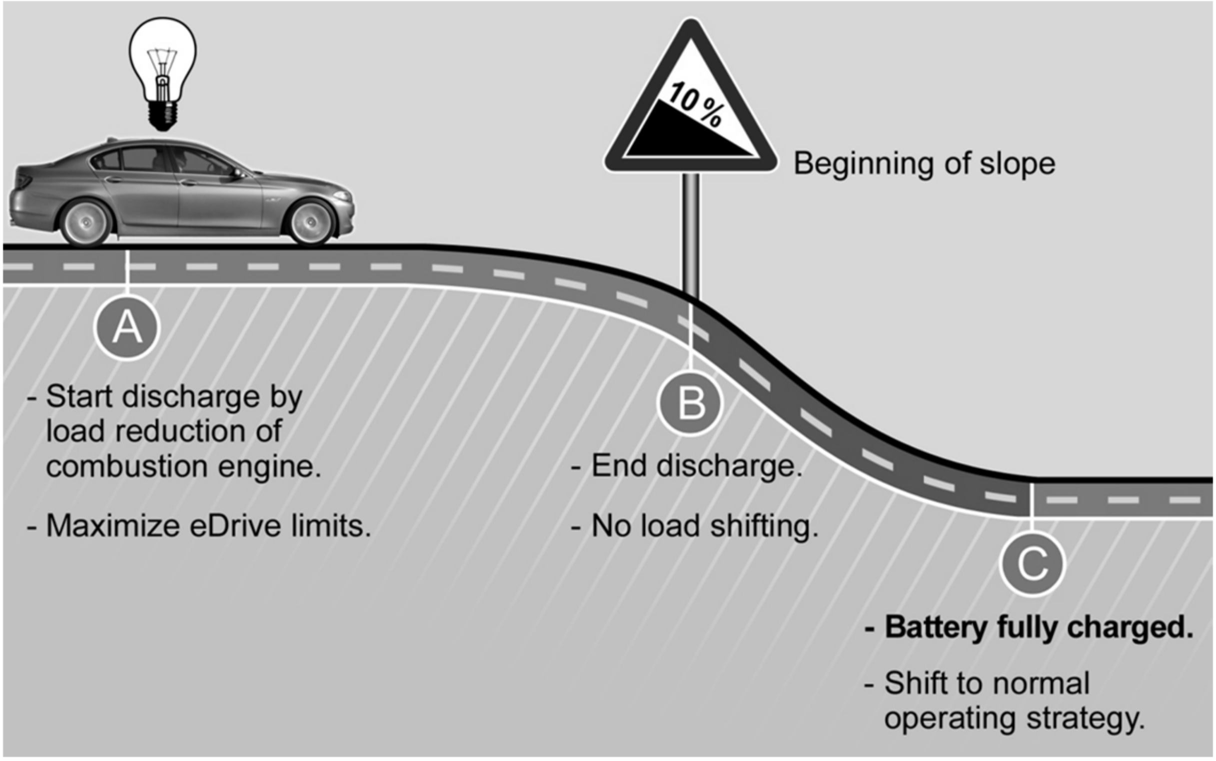


Fig. 6 Predictive operating strategy in a "downhill gradient" situation

- Slow driving zones: If there is a slow driving zone along the calculated route where electric driving is beneficial, electric driving is reduced specifically during the approach to this zone and the battery is being charged per load shifting (Fig. 7). For this, the predicted amount of energy which will be consumed in this zone is taken into consideration. In the slow driving zone the strategy then switches and expands the electric driving range so that the vehicle has stored sufficient electric energy to drive through this zone fully electrically.

- Target zone: Similar to the strategy in the slow driving zone, charging during the approach to the destination also ensures that there is sufficient electrical energy available when the vehicle reaches the target zone (e.g. residential area, car park).

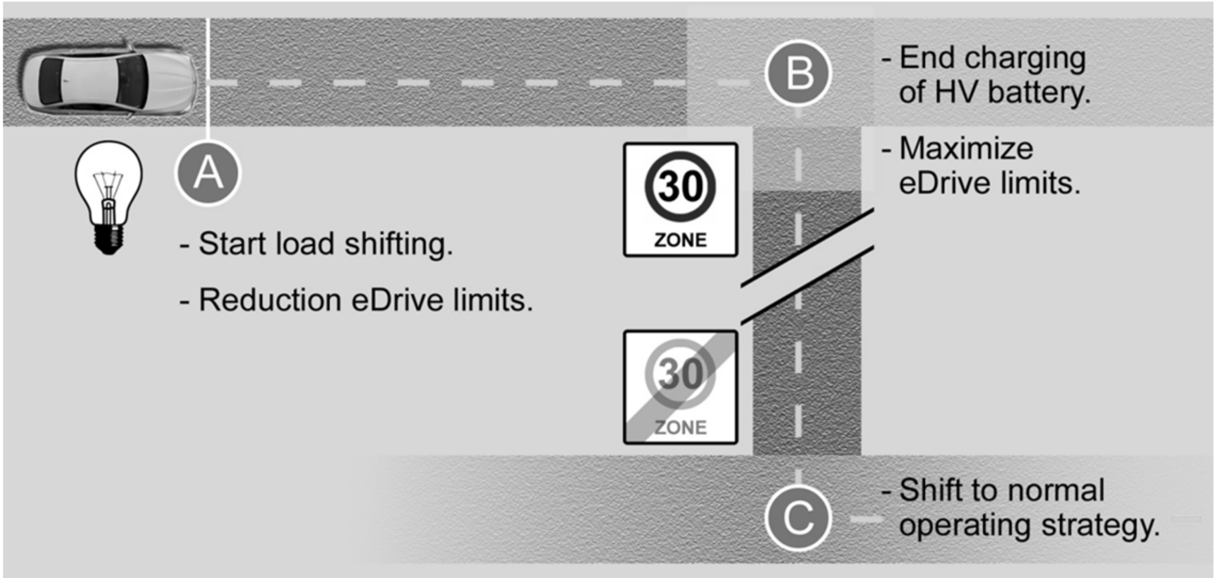


Fig. 7: Predictive operating strategy in the "slow driving zone" situation

In addition to the charging and E-driving strategy, the strategy for battery cooling is also adapted using information on the route ahead and thus the cooling requirement to be expected.

With this innovative connection of vehicle systems the operating strategy can be better adapted to the driving situations and in addition to increased efficiency it also leads to a significant rise in the availability of electric driving. The ActiveHybrid 5 thus features a predictive, or even intelligent operating strategy.

4.2 Start of the combustion engine

By the hybrid operating strategy the request for a start of the combustion engine is determined and consequently the starter unit (SGR) is being activated. Due to the reflex start capability of the SGR without the restrictions of a conventional starter, the engine start can be activated at any time also in an engine coast down to standstill. At the same time, the chosen solution offers the advantage that the entire traction potential of the main E-machine is available for electric drive and no torque reserve has to be formed for a start-up of the combustion engine.

Depending on the dynamic requirement, corresponding downshifts or upshifts are also performed in parallel to the engine start. This results in significant advantages in the dynamic response with excellent start-up comfort at the same time.

4.3 ActiveHybrid Damping function (ASD)

In a conventional drive train longitudinal vibrations are essentially reduced by 2 methods:

1. Filtering of the driver's choice torque
2. Ignition timing interventions so that an existing vibration quickly subsides

The former leads to a delayed torque build-up and therefore a reduced dynamic response. Ignition timing interventions have a negative effect on fuel economy and can also only be used for torque reduction.

These restrictions can be reduced considerably in the hybrid vehicle through the use of the E-machine for vibration damping. The active vibration damping is very important especially in electric driving as this operating point is very susceptible to vibrations due to the disconnected combustion engine and the resulting reduction of the moment of inertia of the drive train. The vibrational behaviour during manoeuvres with strong positive or negative load gradients can be improved significantly. In hybrid driving, the ASD also opens up the possibility of a more dynamic calibration of the driveability functions without negative influences on driving comfort.

The effectiveness of the ASD is shown in Figure 8 using the example of a load step in 1st gear. It is clearly visible how the vehicle acceleration is harmonised through the controlled interventions of the ASD function.

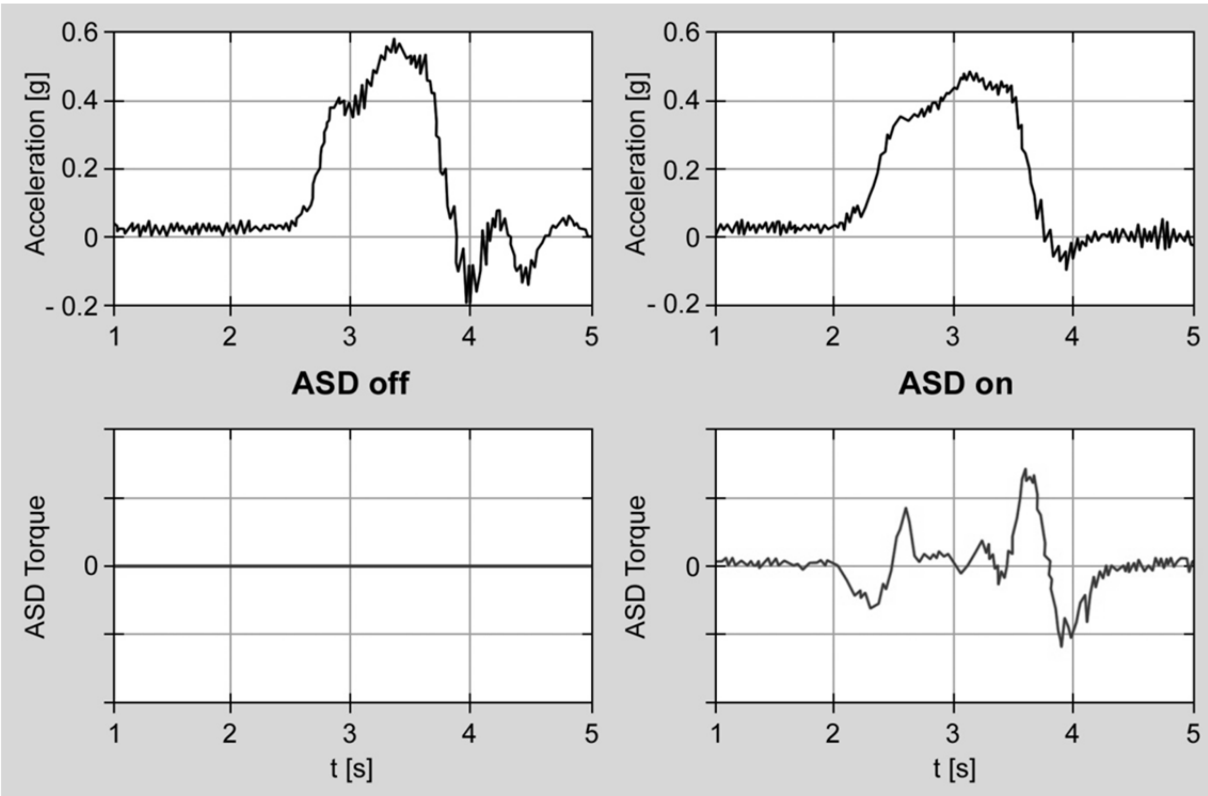


Fig. 8: Operating principle of the ASD function

4.4 CO_2 emissions / vehicle performance results

Due to a consistently fuel consumption-oriented system design and operating strategy it is possible to fully exhaust the CO_2 reduction potential of the hybrid concept. The conventional vehicle, the 535i, is already an excellent starting point: with TwinPower turbocharging, direct fuel injection, 8-speed automatic transmission and Auto Start Stop function, this vehicle achieves a fuel consumption in the NEDC of 7.6 l/100 km and a CO_2 emission of 177 g/km. The ActiveHybrid 5 achieves a fuel consumption of 6.4 l/100 km and a CO_2 emission of 149 g/km, which corresponds to a reduction of 16 % with the full hybrid technology. A maximum system power of 250 kW and a maximum torque of 450 Nm are available. For vehicle performance in the acceleration from 0 to 100 km/h the ActiveHybrid 5 achieves a value of 5.9 s and is therefore at the same level as the conventional vehicle. Figure 9 shows the CO_2 emissions and vehicle performances of the hybrid version in comparison to conventional BMW vehicles and hybrid competitors.

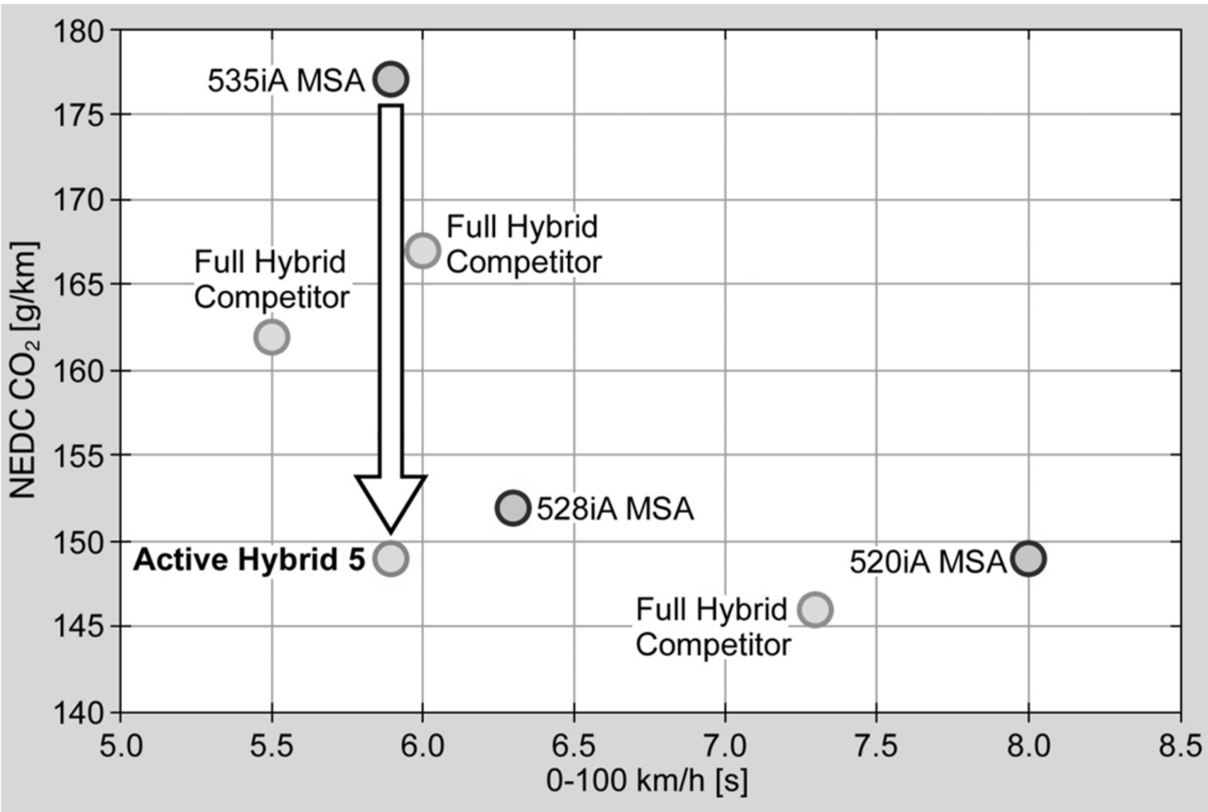


Fig. 9: CO_2 emissions and vehicle performances of the ActiveHybrid 5 in comparison to conventional drives and competitors.

The vehicle achieves the emission levels EU5 and ULEV II. The emission values are even below the Japanese Green Car 4 Star rating. With these characteristics the ActiveHybrid 5 is another significant step within the framework of the Efficient Dynamics strategy of the BMW Group and impressively demonstrates how future-oriented efficiency can be combined with driving dynamics typical for every BMW through hybrid technology.

5 Conclusion

The new ActiveHybrid 5 – another step in a new era of electric mobility.

The aim of the integration of the electric motor in the existing package, with short connections to the power electronics, and the modification of the six cylinder inline engine with an additional starter unit and an electric A/C compressor, have made possible the implementation of a hybrid powertrain in existing development and production solutions.

The fuel economy benefits together with excellent electric driving characteristics give the ActiveHybrid 5 a special character in the area of current hybrid vehicles. The perfect combination of a combustion engine and an electric motor together with an intelligent operating strategy ensure that The Ultimate Driving Machine can be enjoyed also in the future.

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