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(54) Title of the Invention: **Hybrid powertrain**
Abstract Title: **Split hybrid having manual transmission and series mode**

(57) A hybrid powertrain 100 for a vehicle 101 comprises a first wheel drive 105, a second wheel drive 110, an engine 160 having a crankshaft 180, a first motor-generator electric unit 195 coupled to the crankshaft 180, a second motor-generator electric unit 145 coupled to the second wheel drive 110, and an electrical energy storage device 135 connected to both motor-generator electric units 195, 145. A manual transmission 215 coupled to the first wheel drive 105 is drivable by the crankshaft 180 via a clutch 220. An electric actuator 400 is provided for actuating the clutch 220, and an electronic control unit 405 (ECU) is in communication with the electric actuator 400. The clutch may provide disconnection of the transmission when the first motor generator 195 is not operating as a motor, according to a mode of the vehicle. The clutch 220 is operated by the ECU, which may take account of a driver's clutch pedal position. The invention provides a hybrid vehicle with automatic mode control and the efficiency and cost advantages of a manual transmission.

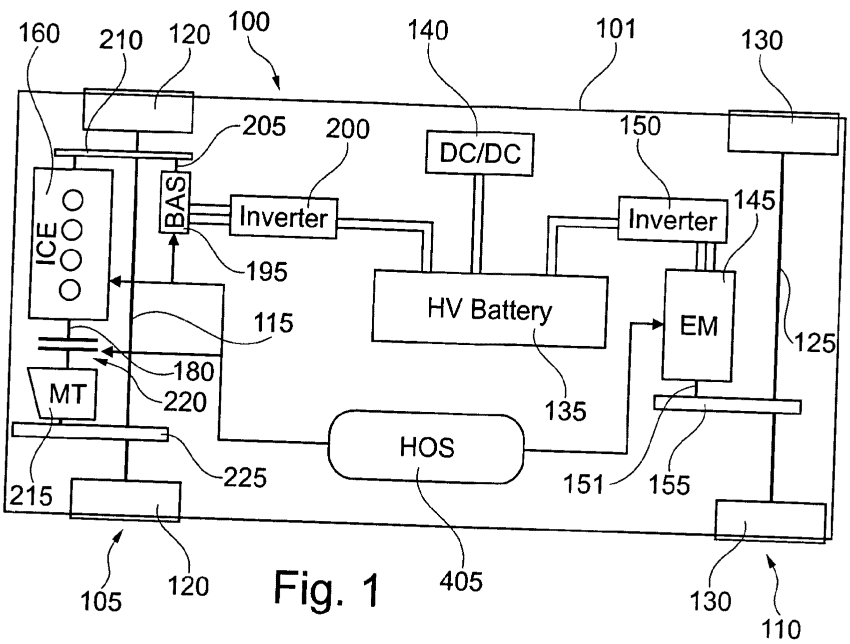

Fig. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

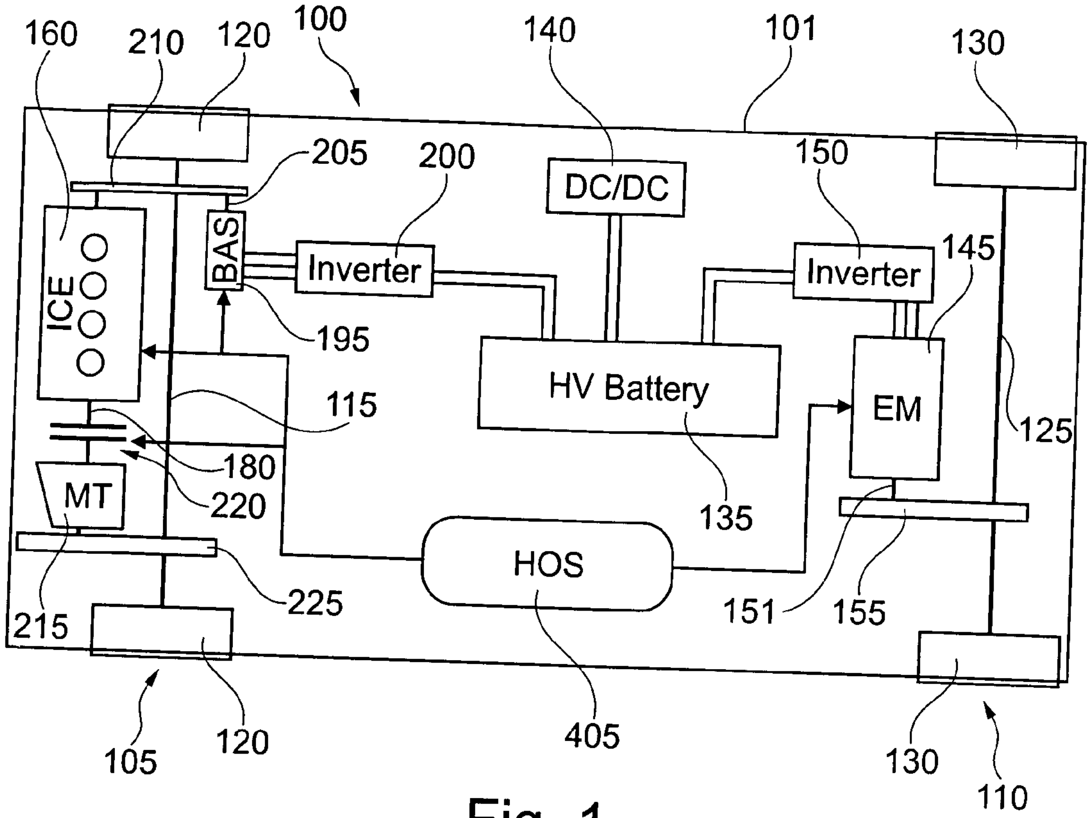
160
210
120
100
140
101
130
205
200
DC/DC
150
BAS
Inverter
Inverter
145
ICE
195
HV Battery
EM
115
125
180
220
MT
135
HOS
225
151
155
215
105
120
405
130
110

Fig. 1

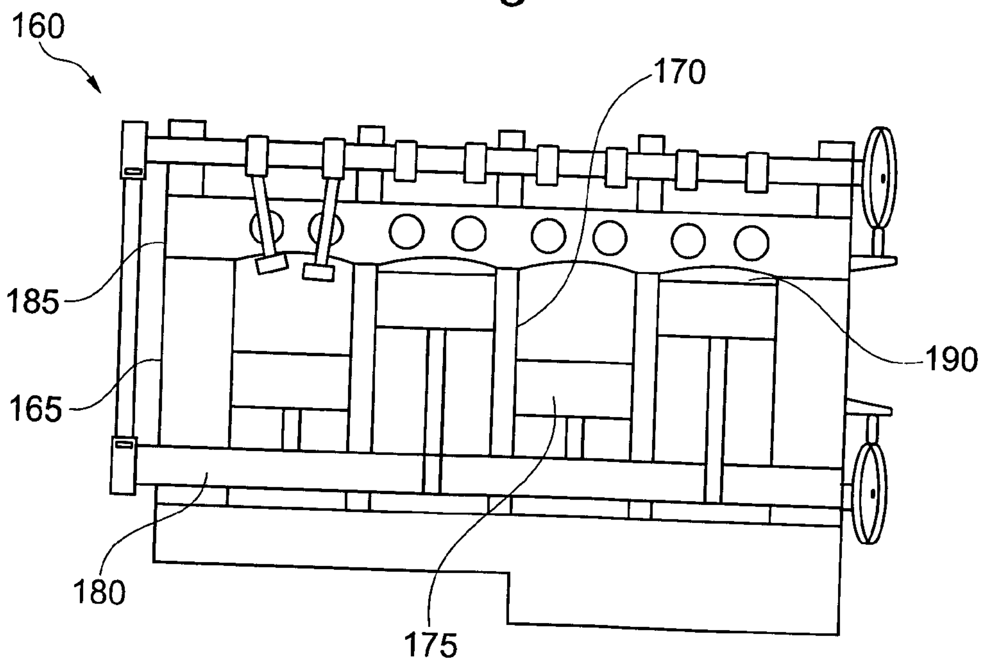
160
170
185
190
165
180
175

Fig. 2

10 13 112

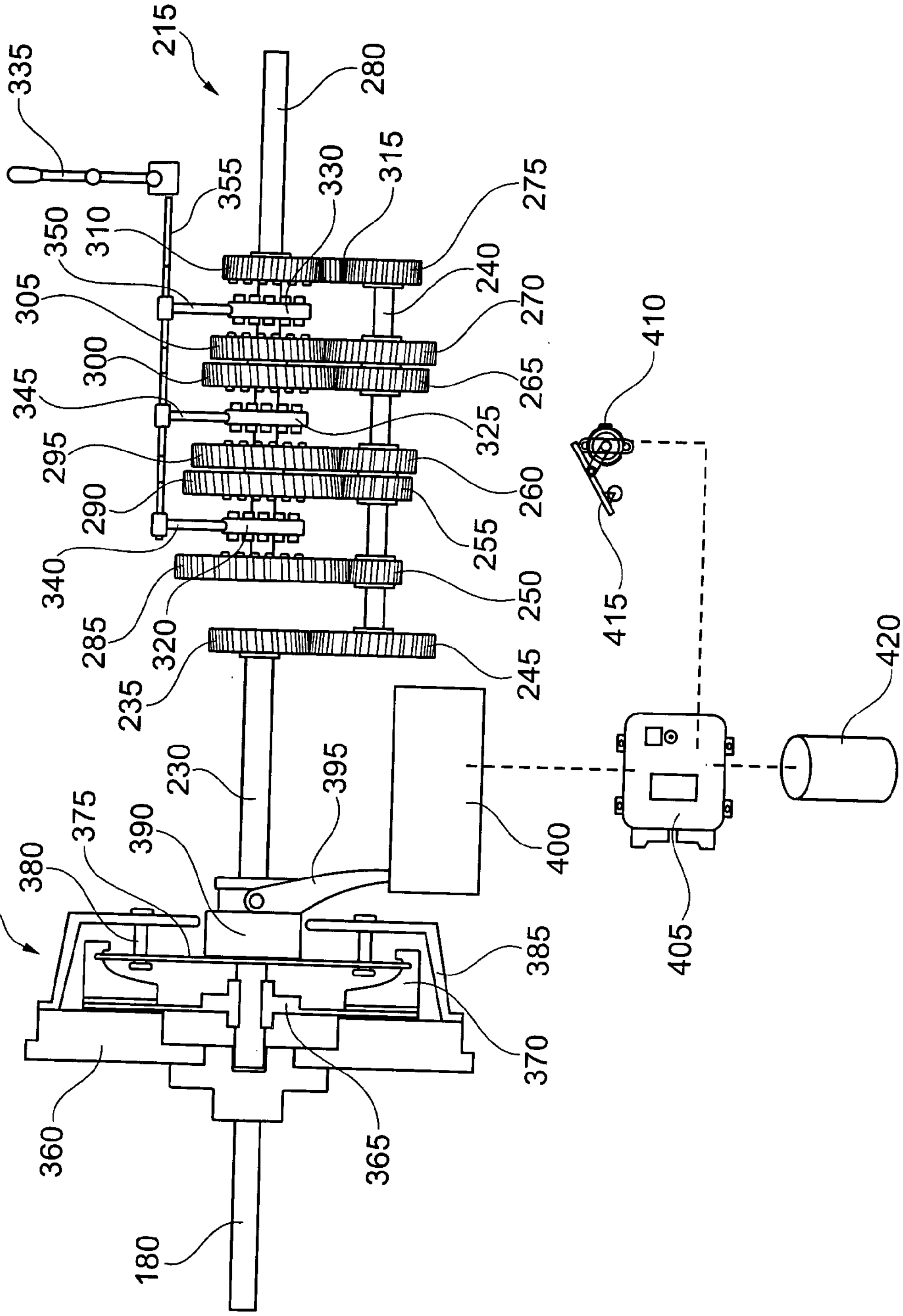

Fig. 3

HYBRID POWERTRAIN

TECHNICAL FIELD

The present invention relates to a hybrid powertrain of a motor vehicle.

BACKGROUND

It is known that any motor vehicle is equipped with a powertrain designed to produce the traction necessary for the motor vehicle to move. A powertrain of a motor vehicle basically comprises at least one power source provided for generating mechanical power, and at least one wheel drive, typically a front wheel drive or a rear wheel drive, which receives the mechanical power form the power source and delivers it to the road surface.

Within this scheme, a hybrid powertrain comprises at least two power sources, including an internal combustion engine (ICE), such as for example a compression-ignition engine (Diesel engine) or a spark-ignition engine (gasoline or gas engine), and a motor-generator electric unit (MGU), which is connected to an electrical energy storage device (battery). The MGU can operate as an electric motor for assisting or replacing the ICE in propelling the motor vehicle, and can also operate as an electric generator, especially when the motor vehicle is braking, for charging the battery.

Among the hybrid powertrains, the so called All-Wheel Drive (AWD) hybrid powertrains comprise an ICE having a crankshaft coupled to supply mechanical power to a first wheel drive, typically the front wheel drive, a first MGU, which is connected to a battery and is coupled to the crankshaft, in order to supply additional mechanical power or absorb mechanical power to/from the first wheel drive, and a second MGU, which is connected to the same battery of the first MGU but it is coupled to supply or absorb mechanical power to/from a second wheel drive, typically the rear wheel drive.

The ICE and the MGUs are in communication with an electronic control unit (ECU), which is configured for determining an operating mode to be performed by the AWD hybrid powertrain, namely for determining whether the first MGU and the second MGU should operate as electric motor, electric generator or be inactive, and for operating the AWD hybrid powertrain accordingly.

In order to allow the ECU to effectively operate these AWD hybrid powertrains, for example in order to allow a pure electric launch or a pure electric cruising of the motor vehicle, the engine crankshaft is usually coupled to the first wheel drive by means of an automatic or semi-automatic transmission controlled by the ECU, such as for example a Continuous Variable Transmission (CVT) or a Dual Clutch Transmission (DCT).

However, these automatic or semi-automatic transmissions have a limited mechanical efficiency, which increases the fuel consumption and the polluting emissions of the AWD hybrid powertrain, and they are also very expensive, thereby increasing the production cost of the AWD hybrid powertrain.

An object of an embodiment of the present invention is therefore to solve the above mentioned drawbacks with a simple, rational and rather cheap solution.

SUMMARY

These and/or other objects are attained by the characteristics of the embodiments of the invention as reported in independent claims. The dependent claims recite preferred and/or especially advantageous features of the embodiments of the invention.

In particular, an embodiment of the invention provides a hybrid powertrain for a motor vehicle, comprising a first wheel drive, a second wheel drive, an internal combustion engine having a crankshaft, a first motor-generator electric unit coupled to the engine crankshaft, a second motor-generator electric unit coupled to the second wheel drive, an electrical energy storage device connected to the first and the second motor-generator electric unit, a manual transmission coupled to the first wheel drive, a clutch coupling the manual transmission to the engine crankshaft, an electric actuator for actuating the clutch, and an electronic control unit in communication with the electric actuator for operating the clutch through the electric actuator.

It should be understood that a manual transmission (also referred as manual gearbox) is a mechanical device that can be actuated by a human driver of the motor vehicle, in order to change (shift) the gear ratio between the engine crankshaft and the first wheel drive. More particularly, the actuation of the manual transmission is purely manual, namely without the aid of any other actuator except the human driver.

The manual transmission is generally cheaper than any other automatic or semi-automatic transmission, so that it advantageously reduces the production cost of the hybrid powertrain. In addition, the manual transmission has generally a greater mechanical efficiency, so that it advantageously reduces also the fuel consumption and the polluting emissions of the hybrid powertrain.

Besides, the use of an electrically actuated clutch operated by the electronic control unit allows the latter to disengage the mechanical transmission from the engine crankshaft independently by the driver will. Thanks to this possibility, the electronic control unit may advantageously have a complete control on the operating modes of the hybrid powertrain.

According to an aspect of the invention, the hybrid powertrain may further comprise a clutch pedal movable from a released position to a pressed position, and a clutch pedal position sensor connected to the electronic control unit for sending input signals thereto.

This aspect of the invention has the advantage of allowing the electronic control unit to operate the clutch taking into account also the position of the clutch pedal.

According to still another aspect of the invention, the first wheel drive is a front wheel drive, and the second wheel drive is a rear wheel drive.

This solution has the advantages of improving stability and vehicle dynamics.

Another embodiment of the invention provides a motor vehicle comprising the hybrid powertrain.

This embodiment of the invention has basically the same advantages of the hybrid powertrain mention above, in particular those of reducing the production cost and of increasing the efficiency of the motor vehicle equipped with the hybrid powertrain.

Still another embodiment of the invention provides a method for operating the hybrid powertrain described above, which comprises the steps of:

- determining an operating mode for the hybrid powertrain,
- operating the hybrid powertrain according to the determined operating mode, and
- operating the clutch on the basis of the operating mode of the hybrid powertrain.

In this way, it is advantageously possible to enhance the effectiveness of some hybrid powertrain operating modes and/or introduce additional hybrid operating modes, in such a way that wouldn't be possible using a manual transmission and a traditional clutch controlled by the human driver.

By way of example, an aspect of the invention provides for the method to comprise the step of operating the clutch to disconnect the engine crankshaft from the manual transmission, if the operating mode of the hybrid powertrain provides for the first motor-generator electric unit to be inactive, namely to operate neither as electric motor nor as electric generator, and for the second motor-generator electric unit to operate as electric generator.

This hybrid powertrain operating mode may be referred as regenerative braking mode, since the second motor-generator electric unit is advantageously used to charge the battery, while the internal combustion engine may be turned off. This regenerative braking mode has a great efficiency, because the internal combustion engine is disengaged from the first wheel drive and thus does not introduces pumping losses in the energy balance.

According to another aspect of the invention, the method may include the step of operating the clutch to disconnect the engine crankshaft from the manual transmission, if the operating mode of the hybrid powertrain provides for the first motor-generator electric unit to be inactive and for the second motor-generator electric unit to operate as electric motor.

This hybrid powertrain operating mode may be referred as pure electric mode, since the motor vehicle is propelled only by the second motor-generator electric unit while the internal combustion engine may be turned off. Also this pure electric mode has a great efficiency, because the internal combustion engine is disengaged from the first wheel drive and thus does not introduces pumping losses in the energy balance.

According to still another aspect of the invention, the method may comprise the step of operating the clutch to disconnect the engine crankshaft from the manual transmission, if the operating mode of the hybrid powertrain provides for the first motor-generator electric unit to operate as electric generator and for the second motor-generator electric unit to operate as electric motor.

This hybrid powertrain operating mode may be referred as serial mode, since the motor vehicle is propelled by the second motor-generator electric unit powered by the battery, which in its turn is contemporaneously charged by the first motor-generator electric unit driven by the internal combustion engine.

Another aspect of the invention provides for the method to comprise the further steps of:

- sensing a position of the clutch pedal, and
- operating the clutch to disconnect the engine crankshaft and the manual transmission, if the clutch pedal is sensed to be in the pressed position.

This aspect of the invention has the advantage of guaranteeing that the engine crankshaft and the manual transmission are mutually disengaged whenever the human driver tries to actuate the manual transmission, thereby preventing potential damages of the manual transmission itself.

The method according to the invention can be carried out with the help of a computer program comprising a program-code for carrying out all the steps of the method described above, and in the form of a computer program product on which the computer program is stored. The method can be also embodied as an electromagnetic signal, said signal being modulated to carry a sequence of data bits which represent a computer program to carry out all steps of the method.

By way of example, the computer program product may be embodied as hybrid powertrain for a motor vehicle, comprising a first wheel drive, a second wheel drive, an internal combustion engine having a crankshaft, a first motor-generator electric unit coupled to the engine crankshaft, a second motor-generator electric unit coupled to the second wheel drive, an electrical energy storage device connected to the first and the second motor-generator electric unit, a manual transmission coupled to the first wheel drive, a clutch coupling the manual transmission to the engine crankshaft, an electric actuator for actuating the clutch, an electronic control unit in communication with the electric actuator, and a memory system in which the computer program is stored.

Another embodiment of the invention provides an apparatus for operating a hybrid powertrain for a motor vehicle, wherein the hybrid powertrain comprises a first wheel drive, a second wheel drive, an internal combustion engine having a crankshaft, a first motor-generator electric unit coupled to the engine crankshaft, a second motor-generator electric unit coupled to the second wheel drive, an electrical energy storage device connected to the first and the second motor-generator electric unit, a manual transmission coupled to the first wheel drive, a clutch coupling the manual transmission to the engine crankshaft, and an electric actuator for actuating the clutch, and wherein the apparatus further comprises:

- means for determining an operating mode for the hybrid powertrain,
- means for operating the hybrid powertrain according to the determined operating mode, and
- means for operating the clutch on the basis of the operating mode of the hybrid powertrain.

This embodiment of the invention has basically the same advantages of the method disclosed above, including that of enhancing the effectiveness of some hybrid powertrain operating modes and/or introducing additional hybrid operating modes.

Still another embodiment of the invention provides an automotive system including a hybrid powertrain which comprises a first wheel drive, a second wheel drive, an internal combustion engine having a crankshaft, a first motor-generator electric unit coupled to the engine crankshaft, a second motor-generator electric unit coupled to the second wheel drive, an electrical energy storage device connected to the first and the second motor-generator electric unit, a manual transmission coupled to the first wheel drive, a clutch coupling the manual transmission to the engine crankshaft, an electric actuator for actuating the clutch, and an electronic control unit in communication with the electric actuator, wherein the electronic control unit is configured to:

- determine an operating mode for the hybrid powertrain,
- operate the hybrid powertrain according to the determined operating mode, and
- operate the clutch on the basis of the operating mode of the hybrid powertrain.

Also this embodiment of the invention has basically the same advantages of the method disclosed above, including that of enhancing the effectiveness of some hybrid powertrain operating modes and/or introducing additional hybrid operating modes.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described, by way of example, with reference to the accompanying drawings.

Figure 1 is a schematic representation of an hybrid powertrain according to an embodiment of the invention.

Figure 2 is a schematic section of an internal combustion engine belonging to the hybrid powertrain of figure 1.

Figure 3 is a more detailed representation of a portion of the hybrid powertrain of figure1.

DETAILED DESCRIPTION

Some embodiments may include a hybrid powertrain 100 of a motor vehicle 101, such as for example an All-wheel drive (AWD) hybrid powertrain, as shown in figures 1.

The hybrid powertrain 100 may comprise two independent wheel drives, including a front wheel drive 105 and a rear wheel drive 110. The front wheel drive 105 schematically comprises a carrying axle 115 and two wheels 120, which are coupled to the carrying axle 115 and are destined to stay on the road surface. Likewise, the rear wheel drive 110 schematically comprises a carrying axle 125 and two wheels 130, which are coupled to the carrying axle 125 and are destined to stay on the road surface.

The hybrid powertrain 100 further comprises an electrical energy storage device, in this example a High Voltage (HV) battery 135. The HV battery 135 may be equipped with a DC/DC converter 140, which is destined to recharge an additional low-voltage (i.e. 12V) battery (not shown) of the motor vehicle 101.

The hybrid powertrain 100 further comprises a rear motor-generator electric unit (MGU) 145, which is connected to the HV battery 135 through an inverter 150. The rear MGU 145 is an Electric Machine (EM), namely an electro-mechanical energy converter, which is able either to convert electricity supplied by the HV battery 135 into mechanical power (i.e., to operate as an electric motor) or to convert mechanical power into electricity that charges the HV battery 135 (i.e., to operate as electric generator).

In greater details, the rear MGU 145 may comprise a rotor, which is arranged to rotate with respect to a stator, in order to generate or respectively receive the mechanical power. The rotor may comprise means to generate a magnetic field and the stator may comprise electric windings connected to the HV battery 135, or vice versa. When the rear MGU 145 operates as electric motor, the HV battery 135 supplies electric currents in the electric windings, which interact with the magnetic field to set the rotor in rotation. Conversely, when the rear MGU 145 operates as electric generator, the rotation of the rotor causes a relative movement of the electric wiring in the magnetic field, which generates electrical currents in the electric windings. The rear MGU 145 may be of any known type, for example a permanent magnet machine, a brushed machine or an induction machine. The rear MGU 145 may also be either an asynchronous or a synchronous machine.

The rotor of the rear MGU 145 comprises a coaxial shaft 151, which is mechanically coupled to the carrying axle 125 of the rear wheel drive 110 through a differential 155. In this way, when the rear MGU 145 operates as electric motor, the mechanical power generated thereby is transferred to the wheels 130, putting them into rotation. Conversely, when the rear MGU 145 operates as electric generator, the rotation of the wheels 130 is transferred to the rotor of the rear MGU 145 charging the HV battery 135.

The hybrid powertrain 100 further comprises an internal combustion engine (ICE) 160, such as for example a diesel engine or a gasoline engine.

As shown in figure 2, the ICE 160 schematically comprises an engine block 165 defining one or more cylinders 170 having a piston 175 coupled to rotate a crankshaft 180. A cylinder head 185 cooperates with the piston 175 to define a combustion chamber 190. A fuel and air mixture (not shown) is disposed in the combustion chamber 190 and ignited, resulting in hot expanding exhaust gasses that cause reciprocal movement of the piston 175, and thus rotational movement of the crankshaft 180.

The hybrid powertrain 100 further comprises a front motor-generator electric unit (MGU) 195, which is connected to the HV battery 135 through an inverter 200. The front MGU 195 is an electric machine, namely an electro-mechanical energy converter, which is able either to convert electricity supplied by the HV battery 135 into mechanical power (i.e., to operate as an electric motor) or to convert mechanical power into electricity that charges the HV battery 135 (i.e., to operate as electric generator).

The basic constructional features of the front MGU 195 may be the same that have been described for the rear MGU 145. However, the front MGU 195 usually has smaller dimensions and lower nominal power than the rear MGU 145.

The rotor of the front MGU 195 may comprise a coaxial shaft 205, which is mechanically coupled to the crankshaft 180 of the ICE 160. In this way, when the front MGU 195 operates as electric motor, the mechanical power generated thereby is transferred to the crankshaft 180, putting it into rotation. Conversely, when the front MGU 195 operates as electric generator, the rotation of the crankshaft 180 is transferred to the rotor of the front MGU 195 charging the HV battery 135. In the present example, the shaft 205 is mechanically coupled to the crankshaft 180 through a transmission belt 210, similarly to a conventional alternator starter, so that the front MGU 195 may be also referred as Belt

Alternator Starter (BAS).

The crankshaft 180 is mechanically coupled to the carrying axle 115 of the front wheel drive 105 through a Manual Transmission (MT) 215, a clutch 220 connecting the manual transmission 215 to the crankshaft 180, and a differential 225 connecting the manual transmission 215 to the carrying axle 115. In this way, the rotation of the crankshaft 180 can be transferred to wheels 120 of the front wheel drive 105, and vice versa.

The manual transmission 215 (also referred as manual gearbox) is a mechanical device that can be actuated by a human driver of the motor vehicle 101, in order to change (shift) the gear ratio between the crankshaft 180 and the wheels 120 of the front wheel drive 105. The actuation of the manual transmission 215 is purely manual, namely without the aid of any other actuator (e.g. electric actuator or the like) except the human driver himself.

The manual transmission 215 of the present example may be a five-speed manual transmission with reverse gear, as shown in figure 3. The manual transmission 215 comprises an input shaft 230, which is coupled to the crankshaft 180 through the clutch 220 and which carries a gear wheel 235. The gear wheel 235 is coupled to the input shaft 230 such as to rotate therewith as a single unit. The manual transmission 215 further comprises a countershaft 240, which carries a gear wheel 245. The gear wheel 245 is coupled to the countershaft 240 such as to rotate therewith as a single unit, and it is in mesh with the gear wheel 235, so that the countershaft 240 and the input shaft 230 are directly connected. In this way, whenever the input shaft 230 is rotating, the countershaft 240 is rotating too, but in opposite directions. The countershaft 240 carries six additional gear wheels, respectively indicated as 250, 255, 260, 265, 270 and 275. Also these six additional gear wheels are coupled to the countershaft 240 such as to rotate therewith as a single unit. The manual transmission 215 further comprises an output shaft 280, which is connected to the carrying axle 115 of the front wheel drive 105 through the differential 225. In this way, whenever the output shaft 280 is rotating, the wheels 120 of the front wheel drive 105 are rotating too, and vice versa. The output shaft 280 carries six gear wheels, respectively indicated as 285, 290, 295, 300, 305 and 310, each of which rides on a respective bearing, so as to be able to freewheeling on the output shaft 280. The gear wheel 285 is in mesh with the gear wheel 250 of the countershaft 240, so as to define the first gear of the manual transmission 215. The gear wheel 290 is in mesh with the gear wheel 255 of the countershaft 240, so as to define the second gear of the manual transmission 215. The gear wheel 295 is in mesh with the gear wheel 260 of the countershaft 240, so as to define the third gear of the manual transmission 215. The gear wheel 300 is in mesh with the gear wheel 265 of the countershaft 240, so as to define the fourth gear of the manual transmission 215. The gear wheel 305 is in mesh with the gear wheel 270 of the countershaft 240, so as to define the fifth gear of the manual transmission 215. Finally, the gear wheel 310 is in mesh with an idle gear wheel 315, which is also in mesh with the gear wheel 275 of the countershaft 240, so as to define the reverse gear of the manual transmission 215.

The output shaft 280 is a splined shaft that carries three collars, including a first collar 320 interposed between the gear wheel 285 and the gear wheel 290, a second collar 325 interposed between the gear wheel 295 and the gear wheel 300, and a third collar 330 interposed between the gear wheel 305 and the gear wheel 310. Each of the collars has an internal spline that matches with the external spline of the output shaft 280, so that it rotates with the output shaft 280 as a single unit, but it can slide thereon to engage either of the gear wheels between which it is interposed. To perform this engagement, the opposite sides of each collar may be provided with frontal teeth, usually referred as dog teeth, which are designed to fit into holes on the sides of the respective gear wheels. In this way, when all the collars 320, 325, and 330 are disengaged from the respective gear wheels (as shown in figure 3), then the manual transmission 215 is in neutral and the output shaft 280 is disconnected from the input shaft 230. When one of the collars 320, 325 or 330 engages one of the respective gear wheels, then the output shaft 280 is actually connected to the input shaft 230.

The sliding movements of the collars 320, 325 and 330 along the splined output shaft 280 is actuated by a manual shifter, in this example a shift lever 335, which is directly moved by the human driver of the motor vehicle 101.

In the present example, each of the collars 320, 325 and 330 is fastened to a corresponding selector fork, respectively indicated with 340, 345 and 350. Each of the selector forks 340, 345 and 350 is fastened to a connecting rod 355. Even if figure 3 shows only one connecting rod 355, it should be understood that there are three connecting rods 355 each of which is fastened to a respective of the selector forks 340, 345 and 350. The shift lever 335 may be selectively coupled with one of the three connecting rods 355, so that the movements of the shift lever 335 may be directly converted into sliding movements of the collars 320, 325 or 330, without any additional actuator.

Turning now to the clutch 220, this device is provided for selectively connecting and disconnecting the crankshaft 180 to/from the input shaft 230 of the manual transmission 215.

The clutch 220 of the present example may comprise a flywheel 360, which is coaxially connected to the crankshaft 180 so as to rotate therewith as a single unit. The clutch 220 may also comprise a clutch plate 365, a pressure plate 370 and a diaphragm spring 375, which are axially connected to the input shaft 230 of the manual transmission 215. More particularly, the clutch plate 365 is axially interposed between the flywheel 360 and the pressure plate 370, wherein the pressure plate 370 is fastened to the external edge of the diaphragm spring 375. Near this external edge, the diaphragm spring 375 is held by a series of pins 380, which are fastened to a clutch cover 385.

The clutch 220 further comprises a throw-out bearing 390, which freewheels on the input shaft 230 and can also axially slide thereon. The throw-out bearing 390 is fastened to a release fork 395, which is connected to an electric actuator 400. The electric actuator 400 may be powered by the HV battery 135.

As long as the electric actuator 400 is inactive, the diaphragm springs 375 pushes the pressure plate 370 against the clutch plate 365, which in turn presses against the flywheel 360. This create a friction between the flywheel 360 and the clutch plate 365, which connects the crankshaft 180 to the transmission input shaft 230, causing them to rotate at the same speed. In this case, the clutch 220 is said to be engaged.

When the electric actuator 400 is activated, it pushes on the release fork 395, which presses the throw-out bearing 390 against the middle of the diaphragm spring 375 towards the clutch plate 365. As the middle of the diaphragm spring 375 is pushed, the pins 380 causes the diaphragm spring 375 to pull the pressure plate 370 away from the clutch plate 365, thereby removing the friction and disconnecting crankshaft 180 from the transmission input shaft 230. In this case, the clutch 220 is said to be disengaged.

The hybrid powertrain 100 may further include an electronic control unit (ECU) 405, which is in communication with the electric actuator 400 and is configured to delivery thereto signals to control the clutch 220.

Furthermore, the ECU 405 may be in communication with a position sensor 410 of a clutch pedal 415, which can be moved by the human driver of the motor vehicle 101 from a released position to a pressed position. If the human driver moves the clutch pedal 415 in the pressed position, then the position sensor 410 sends a corresponding signal to the ECU 405. As a response of this signal, the ECU 405 is programmed to activate the electric actuator 400 in order to disconnect the crankshaft 180 from the transmission input shaft 230. In this way, the ECU 405 guarantees that the clutch 220 is disengaged, whenever the human driver is going to actuate the manual transmission 215 for shifting the gear.

As schematically shown in figure 1, the ECU 405 may be in communication also with one or more sensors and/or devices associated with the ICE 160, the front MGU 195 and the rear MGU 145. More particularly, the ECU 405 may receive input signals from various sensors configured to generate the signals in proportion to various physical parameters associated with the ICE 160, the front MGU 195 and the rear MGU 145. Furthermore, the ECU 405 may generate output signals to various control devices that are arranged to control the operation of the ICE 160, the front MGU 195 and the rear MGU 145.

To perform this tasks, the ECU 405 may include a digital central processing unit (CPU) in communication with a memory system 420 and an interface bus. The memory system 420 may include various storage types including optical storage, magnetic storage, solid state storage, and other non-volatile memory. The interface bus may be configured to send, receive, and modulate analog and/or digital signals to/from the various sensors and control devices, as explained above. The CPU is configured to execute instructions stored as a program in the memory system 420, and send and receive signals to/from the interface bus. The program may embody all the methods that have been already discloses as well as the methods that will be disclosed hereinafter, allowing the CPU to carryout out all the steps of such methods.

More particularly, the ECU 405 may be configured to perform a so called Hybrid Optimization Strategy (HOS). The HOS basically provides for the ECU 405 to determine, on the basis of the current driving conditions and other operating parameters, an optimal operating mode for the hybrid powertrain, namely to determine whether the ICE 160 has to be turned-on or turned-off, whether the front MGU 195 has to operate as electric motor, electric generator or to remain inactive (neutral), and whether the rear MGU 145 has to operate as electric motor, electric generator or to remain inactive. Once the optimal operating mode has been determined, the HOS provides for the ECU 405 to operate and control the hybrid powertrain 100, namely the ICE 160, the front MGU 195, the rear MGU 145 and also the clutch 220, accordingly.

By way of example, the HOS may select the optimal operating mode among the followings: combustion mode, parallel mode, regenerative braking first mode, electric All-wheel drive (eAWD) mode, regenerative braking second mode, and automatic electric mode, and serial mode.

According to the combustion mode, the ICE 160 is turned-on, the front MGU 195 is operated as electric generator, and the rear MGU 145 is kept inactive. In this operating mode, the ECU 405 keeps the clutch 220 normally engaged, so that the motor vehicle 101 is propelled by the ICE 160. The ECU 405 may disengage the clutch 220 if the human driver presses the clutch pedal 415, for example to actuate the manual transmission 215.

According to the parallel mode, the ICE 160 is turned-on, the front MGU 195 is operated as electric motor, and the rear MGU 145 is operated as electric motor too. In this operating mode, the ECU 405 keeps the clutch 220 normally engaged, so that the motor vehicle 101 is propelled by the ICE 160 and by the front MGU 195, as well as by the rear

MGU 145. Also in this case, the ECU 405 may disengage the clutch 220 if the human driver presses the clutch pedal 415, for example to actuate the manual transmission 215.

According to the regenerative braking first mode, the ICE 160 is turned-on, the front MGU 195 is operated as electric generator, and the rear MGU 145 is operated as electric generator too. In this operating mode, the ECU 405 keeps the clutch 220 normally engaged, so that the motor vehicle 101 is propelled by the ICE 160, while the MGUs 145 and 195 charge the HV battery 135. Also in this case, the ECU 405 may disengage the clutch 220 if the human driver presses the clutch pedal 415, for example to actuate the manual transmission 215.

According to the eAWD mode, the ICE 160 is turned-on, the front MGU 195 is operated as electric generator, and the rear MGU 145 is operated as electric motor. In this operating mode, the ECU 405 keeps the clutch 220 normally engaged, so that the motor vehicle 101 is propelled by the ICE 160 and by the rear MGU 145, while the front MGU 195 charges the HV battery 135. Also in this case, the ECU 405 may disengage the clutch 220 if the human driver presses the clutch pedal 415, for example to actuate the manual transmission 215.

According to the regenerative braking second mode, the ICE 160 may be turned-off, the front MGU 195 is kept inactive, and the rear MGU 145 is operated as electric generator to charge the HV battery 135. In this operating mode, the ECU 405 keeps the clutch 220 always disengaged, irrespectively from the position of the clutch pedal 415, so that the ICE 160 does not introduce any pumping loss in the energy balance, thereby increasing the efficiency of the battery recharging.

According to the automatic electric mode, the ICE 160 may be turned-off, the front MGU 195 is kept inactive, and the rear MGU 145 is operated as electric motor to propel the motor vehicle 101. Also in this operating mode, the ECU 405 keeps the clutch 220 always disengaged, irrespectively from the position of the clutch pedal 415, so that the ICE 160 does not introduce any pumping loss in the energy balance, thereby increasing the efficiency of the electrical propulsion.

According to the serial mode, the ICE 160 is turned-on, the front MGU 195 is operated as electric generator, and the rear MGU 145 is operated as electric motor. In this operating mode, the ECU 405 keeps the clutch 220 always disengaged, irrespectively from the position of the clutch pedal 415, so that the ICE 160 actuates the front MGU 195 to charge the HV battery 135, while the motor vehicle 101 is propelled by the rear MGU 145.

While at least one exemplary embodiment has been presented in the foregoing summary and detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration in any way. Rather, the forgoing summary and detailed description will provide those skilled in the art with a convenient road map for implementing at least one exemplary embodiment, it being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope as set forth in the appended claims and in their legal equivalents.

REFERENCES

100	hybrid powertrain
101	motor vehicle
105	front wheel drive
110	rear wheel drive
115	carrying axle
120	wheels
125	carrying axle
130	wheels
135	HV battery
140	DC/DC converter
145	rear MGU
150	inverter
151	shaft
155	differential
160	ICE
165	engine block
170	cylinder
175	piston
180	crankshaft
185	cylinder head
190	combustion chamber
195	front MGU
200	inverter
205	shaft
210	transmission belt
215	manual transmission
220	clutch
225	differential
230	input shaft
235	gear wheel
240	countershaft
245	gear wheel
250	gear wheel

255	gear wheel
260	gear wheel
265	gear wheel
270	gear wheel
275	gear wheel
280	output shaft
285	gear wheel
290	gear wheel
295	gear wheel
300	gear wheel
305	gear wheel
310	gear wheel
315	idle gear wheel
320	first collar
325	second collar
330	third collar
335	shift lever
340	selector fork
345	selector fork
350	selector fork
355	connecting rod
360	flywheel
365	clutch plate
370	pressure plate
375	diaphragm spring
380	pin
385	clutch cover
390	throw-out bearing
395	release fork
400	electric actuator
405	ECU
410	position sensor
415	clutch pedal
420	memory system

CLAIMS

1. A hybrid powertrain (100) for a motor vehicle (101), comprising a first wheel drive (105), a second wheel drive (110), an internal combustion engine (160) having a crankshaft (180), a first motor-generator electric unit (195) coupled to the engine crankshaft (180), a second motor-generator electric unit (145) coupled to the second wheel drive (110), an electrical energy storage device (135) connected to the first and the second motor-generator electric unit (195, 145), a manual transmission (215) coupled to the first wheel drive (105), a clutch (220) coupling the manual transmission (215) to the engine crankshaft (180), an electric actuator (400) for actuating the clutch (220), and an electronic control unit (405) in communication with the electric actuator (400) for operating the clutch (220) through the electric actuator (400).

2. A hybrid powertrain (100) according to claim 1, comprising a clutch pedal (415) movable from a released position to a pressed position, and a clutch pedal position sensor (410) connected to the electronic control unit (405) for sending input signals thereto.

3. A hybrid powertrain (100) according to any of the preceding claims, wherein the first wheel drive (105) is a front wheel drive, and the second wheel drive (110) is a rear wheel drive.

4. A motor vehicle (101) comprising a hybrid powertrain (100) according to any of the preceding claims.

5. A method for operating a hybrid powertrain (100) according to any of the claims from 1 to 3, wherein the method comprises the steps of:

- determining an operating mode for the hybrid powertrain (100),
- operating the hybrid powertrain (100) according to the determined operating mode, and
- operating the clutch (220) on the basis of the operating mode of the hybrid powertrain (100).

6. A method according to claim 5, comprising the step of operating the clutch (220) to disconnect the engine crankshaft (180) from the manual transmission (215), if the operating mode of the hybrid powertrain (100) provides for the first motor-generator electric unit (195) to be inactive and for the second motor-generator electric unit (145) to operate as electric generator.

7. A method according to claim 5 or 6, comprising the step of operating the clutch (220) to disconnect the engine crankshaft (180) from the manual transmission (215), if the operating mode of the hybrid powertrain (100) provides for the first motor-generator electric unit (195) to be inactive and for the second motor-generator electric unit (145) to operate as electric motor.

8. A method according to any the claims from 5 to 7, comprising the step of operating the clutch (220) to disconnect the engine crankshaft (180) from the manual transmission (215), if the operating mode of the hybrid powertrain (100) provides for the first motor-generator electric unit (195) to operate as electric generator and for the second motor-generator electric unit (145) to operate as electric motor.

9. A method according to any of the claims from 5 to 8, comprising the further steps of:

- sensing a position of a clutch pedal (415) which is movable from a released position to a pressed position, and
- operating the clutch (220) to disconnect the engine crankshaft (180) and the manual transmission (215), if the clutch pedal (415) is sensed to be in the pressed position.

10. A computer program comprising a computer code suitable for performing the method according to any of the claims from 5 to 9.

11. A computer program product on which the computer program of claim 10 is stored.

12. A hybrid powertrain (100) for a motor vehicle (101), comprising a first wheel drive (105), a second wheel drive (110), an internal combustion engine (160) having a crankshaft (180), a first motor-generator electric unit (195) coupled to the engine crankshaft (180), a second motor-generator electric unit (145) coupled to the second wheel drive (110), an electrical energy storage device (135) connected to the first and the second motor-generator electric unit (195, 145), a manual transmission (215) coupled to the first wheel drive (105), a clutch (220) coupling the manual transmission (215) to the engine crankshaft (180), an electric actuator (400) for actuating the clutch (220), an electronic control unit (405) in communication with the electric actuator (400), and a memory system (420) in which the computer program of claim 10 is stored.

13. An apparatus for operating a hybrid powertrain (100) for a motor vehicle (101), wherein the hybrid powertrain (100) comprises a first wheel drive (105), a second wheel drive (110), an internal combustion engine (160) having a crankshaft (180), a first motor-generator electric unit (195) coupled to the engine crankshaft (180), a second motor-generator electric unit (145) coupled to the second wheel drive (110), an electrical energy storage device (135) connected to the first and the second motor-generator electric unit (195, 145), a manual transmission (215) coupled to the first wheel drive (105), a clutch (220) coupling the manual transmission (215) to the engine crankshaft (180), and an electric actuator (400) for actuating the clutch (220), and wherein the apparatus further comprises:

- means (405) for determining an operating mode for the hybrid powertrain (100),
- means (405) for operating the hybrid powertrain (100) according to the determined operating mode, and

- means (405) for operating the clutch (220) on the basis of the operating mode of the hybrid powertrain (100).

14. An automotive system including a hybrid powertrain (100) which comprises a first wheel drive (105), a second wheel drive (110), an internal combustion engine (160) having a crankshaft (180), a first motor-generator electric unit (195) coupled to the engine crankshaft (180), a second motor-generator electric unit (145) coupled to the second wheel drive (110), an electrical energy storage device (135) connected to the first and the second motor-generator electric unit (195, 145), a manual transmission (215) coupled to the first wheel drive (105), a clutch (220) coupling the manual transmission (215) to the engine crankshaft (180), an electric actuator (400) for actuating the clutch (220), and an electronic control unit (405) in communication with the electric actuator (400), wherein the electronic control unit (405) is configured to:

- determine an operating mode for the hybrid powertrain (100),
- operate the hybrid powertrain (100) according to the determined operating mode, and
- operate the clutch (220) on the basis of the operating mode of the hybrid powertrain (100).

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Claims searched: 1-14 **Date of search:** 24 May 2012

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	JP2006069386 A (NISSAN)
A	-	JP2004274917 A (HITACHI)
A	-	US2004/0147366 A1 (AOKI)

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X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

B60K; B60W

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI, TXTE

International Classification:

Subclass	Subgroup	Valid From
B60K	0006/442	01/10/2007
B60K	0006/36	01/10/2007
B60K	0006/387	01/10/2007
B60K	0006/52	01/10/2007
B60W	0010/02	01/01/2006
B60W	0020/00	01/01/2006