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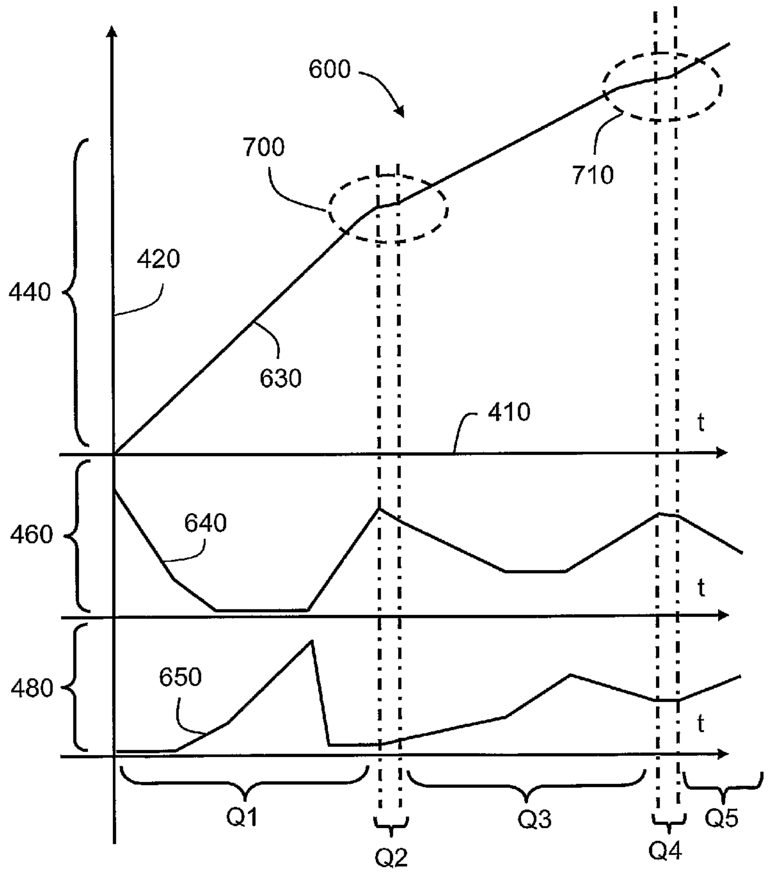

(57) Abstract: There is provided a hybrid powertrain (10) including (i) a combustion engine (20) operable to output rotational power thereat, (ii) an electric machine arrangement (60) being operable to output rotational power thereat, (iii) a gearbox arrangement (200) for receiving rotational power from at least one of the combustion engine (20) and the electric machine arrangement (60), and being operable to couple motive power to a load (230) coupled to the gearbox arrangement (200). The gearbox arrangement (200) is operable to provide a plurality of gearing ratios. The electric machine arrangement (60) is employable to extend a rotation rate range provided in a given gearing ratio: (a) at higher rotation rates prior to a gear change from said given gearing ratio to a gearing ratio subsequent thereto; or (b) at both lower rotation rates when accelerating from a standstill or from a preceding gear, and at higher rotation rates prior to a gear change from said given gearing ratio to a gearing ratio subsequent thereto.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

HYBRID POWERTRAIN

Field of the invention

The present invention relates to hybrid powertrains for systems, for example for passenger vehicles, buses, trucks, boats, ships, trams, trains and similar. Moreover, the invention also concerns methods of controlling such powertrains, for example with regard to gear change. Furthermore, the present invention also relates to vehicles and similar including such powertrains. Additionally, the present invention relates to software executable on computing hardware for executing the methods of controlling such powertrains.

Background to the invention

In recent years, considerable research has been invested in hybrid system technology in order to provide enhanced fuel economy as well as improved motive performance. Hybrid systems include hybrid powertrains, wherein each powertrain usually comprises a combustion engine, an electric machine arrangement, an electrical storage element and a transmission arrangement for coupling at least the electric machine arrangement to a load of the system. The electric machine is optionally implemented as a motor/generator. Superficially, such hybrid powertrains would seem to involve additional complexity and potentially added weight which would be deleterious to system performance. However, in practice several benefits arise from employing hybrid powertrains in comparison to conventional simple combustion engine systems which operate sub-optimally, especially in stop-start scenarios.

One considerable benefit provided by hybrid powertrains is rapid acceleration of a corresponding vehicle from standstill. Such rapid acceleration is achievable on account of electric motors being capable of developing relatively high starting torques, for example in the order of 1000 Nm, at low motor rotor rotation rates. Moreover, rechargeable batteries of hybrid power trains are capable of delivering enormous peak powers of several ten's or even hundred's of kilowatts. In regard to vehicles equipped with such hybrid powertrains it is conventional contemporary practice to employ combustion engines in said hybrid powertrains to propel the vehicles when higher vehicle speeds have been attained whereat electric motors are not capable of providing any advantage. For example, combustion engines of hybrid powertrains are primarily used to provide motive power when their vehicles are cruising at high speeds on motorways. In urban traffic wherein frequent stop-start cycles are experienced, electric motors of hybrid powertrains are used to a considerable extent.

In a published international PCT patent application no. WO2005/016681, there is described a method of controlling a drive unit of a motor vehicle. The drive unit comprises an internal combustion engine and an electric motor. A main transmission arrangement of the drive unit includes an output shaft that is rotationally coupled to a drive shaft of the motor vehicle. The transmission arrangement further includes an input shaft which is connected to the internal combustion engine. The electric motor is coupled to the input shaft or to the output shaft of the transmission arrangement via an intermediate transmission encompassing at least two transmission steps.

In operation, the vehicle is initially driven exclusively by the electric motor in order to accelerate the vehicle from a standstill coincident with the intermediate transmission being on its lowest transmission step. The combustion engine takes over the driving function prior to a shifting process of the intermediate transmission. The intermediate transmission is optionally implemented as a dog-clutch transmission.

The drive unit described in the aforementioned PCT application is well adapted for passenger cars operable to transport people seated within the cars.

The inventor has appreciated that such a manner of operation of the drive unit is suitable for vehicles such as passenger cars, but is sub-optimal for larger vehicles such as buses and trucks, especially when such buses and trucks are used in dense traffic in urban environments wherein frequent stop-start cycles are encountered. Moreover, in crowded buses, people are often standing on account of a lack of seating capacity which places further constraints that acceleration and deceleration of the crowded buses must be smooth and uniform without periods of loss of transmission power propelling the crowded buses. Such smooth transmission characteristics are obtained in contemporary hybrid powertrains in vehicles by using electric motors to initially provide acceleration of the vehicles and then invoking torque from combustion engines once the vehicles have attained appreciable speed prior to invoking a sequence of gear changes. However, the inventor has found that such contemporary hybrid powertrains are not capable of providing sufficiently smooth and uniform acceleration and deceleration.

Thus, the present invention is concerned with addressing a problem that contemporary powertrains are not capable of providing a sufficiently smooth and uniform acceleration.

Summary of the invention

An object of the present invention is to provide a provide an improved hybrid powertrain which is capable of providing more smooth and uniform acceleration and deceleration.

The invention concerns a powertrain as claimed in independent claim 1 and a method of operating a powertrain as claimed in independent claim 5. Associated dependent sub-claims claim desirable features for the powertrain and method according to the invention.

According to a first aspect of the invention, there is provided a hybrid powertrain including:

- a combustion engine operable to output rotational power thereat;
- an electric machine arrangement operable to output rotational power thereat;
- a gearbox arrangement for receiving rotational power from at least one of the combustion engine and the electric machine arrangement, the gearbox arrangement being operable to couple corresponding motive power to a load;
- wherein the gearbox arrangement is operable to provide a plurality of gearing ratios; and
- wherein the electric machine arrangement is employable to extend a rotation rate range provided in a given gearing ratio:
  (a) at higher rotation rates prior to a gear change from said given gearing ratio to a gearing ratio subsequent thereto; or
  (b) at both lower rotation rates when accelerating from a standstill or from a preceding gear, and at higher rotation rates prior to a gear change from said given gearing ratio to a gearing ratio subsequent thereto.

The invention is of advantage in that use of the electric machine arrangement to extend a range of rotation rates employable in at least the first gearing ratio is capable of reducing a frequency of gear changes, thereby providing for smoother and more uniform acceleration and deceleration.

The electric machine arrangement is beneficially couplable to an energy storage arrangement for providing electrical power to the electric machine arrangement in operation.

The powertrain is beneficially provided with a control arrangement for controlling operation of the powertrain. Further, the powertrain is beneficially provided with a coupling arrangement operable to couple rotational power between the combustion engine and the electric machine arrangement.

Preferably, in the powertrain, the coupling arrangement of the powertrain is operable to at least partially decouple the combustion engine from the gearbox arrangement at the higher rotation rates. More preferably, in the powertrain, the coupling arrangement is operable to fully decouple the combustion engine from the gearbox arrangement at the higher rotation rates. At least partly decoupling the combustion engine reduces a risk of damaging the engine by over-revving it and also is susceptible to reducing friction in the powertrain, thereby improving its efficiency.

Preferably, in the powertrain, the combustion engine is operable in each of the gearing ratios to deliver its maximum power at substantially a middle portion of the rotation range of the gearing ratio, with the electric machine arrangement providing its maximum towards lower and upper rotation rate limits of the gearing ratio. Such use of the electric machine arrangement at both rotation rate ranges of a given gearing ratio is in contradistinction to contemporary practice whereat power delivered from a combustion engine is normally used at relative higher rotation rates in the given gearing ratio.

According to a second aspect of the invention, there is provided a method of controlling a hybrid powertrain including:

- a combustion engine operable to output rotational power thereat;
- an electric machine arrangement being operable to output rotational power thereat;
- a gearbox arrangement for receiving rotational power from at least one of the combustion engine and the electric machine arrangement, the gearbox arrangement being operable to couple corresponding motive power to a load;
- wherein the gearbox arrangement is operable to provide a plurality of gearing ratios,

the method including steps of:

(a) employing the electric machine arrangement to extend a rotation rate range provided in a given gearing ratio at lower rotation rates when accelerating from a standstill or a preceding gearing ratio, and to extend a rotation rate range provided in the given gearing ratio at higher rotation rates prior to a gear change from said given gearing ratio to a gearing ratio subsequent thereto; or

(b) employing the electric machine arrangement to extend a rotation rate range provided in the given gearing ratio at higher rotation rates prior to a gear change from said given gearing ratio to a gearing ratio subsequent thereto.

Preferably, the method includes a step of using a coupling arrangement of the powertrain to at least partially decouple the combustion engine from the gearbox arrangement at the higher rotation rates. More preferably, in the method, the coupling arrangement is operable to fully decouple the combustion engine from the gearbox arrangement at the higher rotation rates.

Preferably, in the method, the combustion engine is operable in each of the gearing ratios to deliver its maximum power at substantially a middle portion of the rotation range of the gearing ratio, with the electric machine arrangement providing its maximum towards lower and upper rotation rate limits of the gearing ratio.

According to a third aspect of the invention, there is provided a system including a hybrid powertrain according to the first aspect of the invention.

Preferably, the system is operable to control its hybrid powertrain using a method according to the second aspect of the invention.

Preferably, the system is a bus, a truck, a van, a passenger vehicle, a tram, a train, a boat, a ship, or a stationary power-delivering device.

According to a fourth aspect of the invention, there is provided a computer product executable on computing hardware for implementing a method according to the second aspect of the invention.

According to a fifth aspect of the invention, there is provided a computer product comprising computer program code means adapted to perform a method or for use in a method according to the second aspect of the invention when the computer program is run on a programmable microcomputer.

Preferably, the computer program is adapted to be downloaded to a powertrain according to the first aspect of the invention or one or more of its components when run on a computer which is connected to the Internet.

According to a sixth aspect of the invention, there is provided a computer program product stored on a computer readable medium, comprising computer program code means according to the fifth aspect of the invention.

It will be appreciated that features of the invention are susceptible to being combined in any combination without departing from the scope of the invention as defined by the accompanying claims.

Description of the diagrams

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings wherein:

Figure 1 is a schematic illustration of a hybrid powertrain pursuant to the present invention;

Figure 2 is a graph illustrating acceleration of a vehicle including the hybrid powertrain of Figure 1, the powertrain operating in a conventional contemporary manner; and

Figure 3 is a graph illustrating acceleration of the a vehicle including the hybrid powertrain of Figure 1, the powertrain operating in a manner pursuant to the present invention.

Description of embodiments of the invention

In the following, an embodiment of a hybrid powertrain pursuant to the present invention will be described. Thereafter, operation of the hybrid powertrain will be elucidated. Alternative implementations of the hybrid powertrain will then be described.

While in the following the invention is exemplified in an embodiment of a hybrid powertrain for a vehicle this implies in no way any restriction in regard of the application field of the invention. On the contrary, the invention is usable also in many other application fields as for instance in hybrid powertrains for trains, boats, ships and stationary applications.

Referring now to Figure 1, there is illustrated a hybrid powertrain indicated generally by 10. The hybrid powertrain 10 is designed to include relatively few component parts for ensuring enhanced reliability and compactness. Moreover, many of its parts are adaptations of well proven components used in vehicles throughout the world. However, the hybrid powertrain 10 differs from known powertrains in several important aspects which will be elucidated further later.

The powertrain 10 includes a combustion engine 20 with its associated exhåust manifold 30. The engine 20 can either be normally aspirated or turbo-changed. Optionally, the engine 20 is a diesel engine, a biogas engine or a petrol engine. An output crankshaft 40 of the combustion engine 20 is rotationally coupled to a first plate of a clutch 50. A second plate of the clutch 50 is rotationally coupled via a further shaft to an electric machine arrangement 60. The clutch 50 is a slipping-type clutch which provides a torque coupling characteristic; the clutch 50 is continuously adjustable from fully disengaged to fully engaged and degrees of torque coupling therebetween.

The electric machine arrangement 60 includes at least one electric machine 70 which not only is operable to generate rotational mechanical power and thus drive torque when excited by electrical energy, but is also operable to function as a generator when configured to provide regenerative braking and thus braking torque; conveniently, the electric machine 70 is capable of functioning both as a motor and as a generator. The electric machine arrangement 60 further includes an output shaft 80 rotationally coupled to the electric machine 70 and also to the output crankshaft 40 of the combustion engine 20 as illustrated. Additionally, the electric machine arrangement 60 includes an electric machine control unit 90 and a power electronics unit 100 for switching high-current to and from the electric machine 70 in response to it functioning as a drive motor or generator.

The powertrain 10 also includes an energy storage arrangement 150. The energy storage arrangement 150 comprises an energy store element 160 which is optionally implemented as a rechargeable battery electrically coupled to an energy storage element controller 170 for managing discharging and recharging of the energy storage element 160. As alternative, the energy storage element 160 is optionally implemented using nickel metal hydride (NiMH) battery technology, advanced lead acid rechargeable battery technology, lithium ion cell technology, or lithium polymer technology. The use of super-capacitors as energy storage elements 160 is also possible. Alternatively, the energy storage element 160 can be implemented by way of a rotating flywheel energy storage device, a hydraulic storage device, a mechanical energy storage device combined with any suitable energy converting arrangement (not shown) converting (i) electrical energy produced by the electric machine 70 (functioning as generator) into an energy form suitable for storage in said energy storage element 160 and (ii) energy stored in said energy storage element 160 into electrical energy for use in the electric machine 70 (functioning as motor). Yet more optionally, the energy storage element 160 can be implemented as a combination of several such energy storage technologies to best utilize individual charging and discharging characteristics of these technologies.

The powertrain 10 and its vehicle have associated therewith electrical auxiliaries 180, for example one or more of electrical heaters, fans, safety systems and vehicle climate control functions. These electrical auxiliaries 180 are electrically coupled to the energy storage element 160 as illustrated in Figure 1.

The aforementioned output shaft 80 is rotationally coupled to a gearbox 200. The gearbox 200 is operable to provide several discrete gearing ratios and a neutral coupling from the output shaft 80 to a final out shaft 210. The final output shaft 210 is rotationally coupled via a differential gear 220 to a load 230 of the powertrain 10, for example one or more wheels 230 of a vehicle (not shown) in which the powertrain 10 is mounted. The vehicle is optionally a heavy duty vehicle such as a bus, a truck, a construction vehicle, a delivery van, or any other type of vehicle which is required in operation to exhibit relatively high smooth and uniform acceleration in a stop-start manner of driving. However, the present invention is not limited to such vehicles; for example, the powertrain 10 is susceptible to being employed in passenger vehicles, boats, ships and stationary power-delivery equipment.

The powertrain 10 is additionally provided with a central control unit 300 electrically coupled to an actuator assembly (not shown) associated with the clutch 50, to the electric machine control unit 90, to the energy storage element controller 170, and to an actuator unit (not shown) associated with the gearbox 200. The central control unit 300 is operable to provide an interface to a driver of the vehicle, for example, the central control unit 300 is coupled to receive acceleration, braking and gear-change commands from the driver. Moreover, although not illustrated in Figure 1, the powertrain 10 includes sensors at various strategic positions in the powertrain 10 for measuring the torque, or measuring parameter signals allowing the subsequent calculation or estimation of the torque; the sensors are beneficially implemented as rotation rate sensors, for example optical or inductive rotation rate sensors implemented as optical or inductive encoders, operable to generate signals; from the signals a measure of torque can be derived from angular acceleration $^{d\omega}/_{dt}$ pursuant to Equation 1 (Eq. 1):

$$T = I\frac{d\omega}{dt} \qquad \text{Eq. 1}$$

wherein

T = torque; and

I = moment of inertia.

The central control unit 300 is operable to perform various functions which will be elucidated later concerning interaction of the combustion engine 20, the clutch 50, the electric machine arrangement 60 and the gearbox 200. Optionally, the electric machine arrangement 60 is implemented by one or more: switched reluctance technology, induction motor/generator technology, permanent magnet technology.

Operation of the powertrain 10 will now be described with reference to Figure 1. The control unit 300 is programmed to activate the combustion engine 20 periodically so as to operate it at a most efficient part of its thermal operating regime so as to enable the combustion engine 20 to provide enhanced fuel economy for the powertrain 10. There are therefore periods during which the combustion engine 20 is in a deactivated state without fuel being supplied thereto. When the combustion engine 20 is in the deactivated state, the clutch 50 is beneficially actuated by the control unit 300 to be in a disengaged state. As described earlier, the clutch 50 is at least partially engaged to couple torque from the combustion engine 20 when the engine 20 is in its activated state with fuel supplied thereto. The control unit 300 is programmed to control the operation of the electric machine arrangement 60, the clutch 50 and the combustion engine 20 so that deactivation and activation of the combustion engine 20 occurs in the powertrain 10 without substantially inducing any noticeable jerks. Such a characteristic is especially important when the powertrain 10 is employed in a bus which transports in operation passengers in a standing position, the bus being required to accelerate smoothly and rapidly in urban environments so as not to unduly impede traffic flow and yet be as fuel efficient as possible to meet economic and fuel emission constraints.

Conventional contemporary operation of the powertrain 10 will now be described with reference to Figure 2. In Figure 2, there is shown a first graph indicated generally by 400. The first graph 400 includes an abscissa axis 410 denoting elapsed time from left to right. Moreover, the first graph 400 includes an ordinate axis 420 subdivided into first, second and third regions 440, 460, 480. In the first region 440 the ordinate axis 420 denotes increasing vehicle speed from bottom to top. In the second region 460, the ordinate axis 420 denotes motive power delivered from the electric machine 70 with power increasing from bottom to top. In the third region 480, the ordinate axis 420 denotes motive power delivered from the combustion engine 20 via the clutch 50 with power increasing from bottom to top. Acceleration of the vehicle is shown as a sequence of phases commencing with phase P1 and ending with phase P5; there are further phases beyond phase P5 which are not described. In a process of progressing from the phase P1 to the phase P5, the speed of the vehicle follows a curve 430 included in the first region 440, power delivered from the electric machine 70 follows a curve 450 in the second region 460, and power delivered from the combustion engine 20 follows a curve 470 in the third region 480. The phases P1, P3 and P5 correspond to acceleration of the vehicle . The phases P2 and P4 correspond to gear changes occurring in the gearbox 200. The first graph 400 corresponds substantially to a regime adopted in the aforementioned published international PCT application no. WO2005/016681.

At a time just prior to the phase P1, the vehicle including the hybrid powertrain 10 is stationary. During the phase P1, initial acceleration occurs using power delivered substantially from the electric machine 70 to a threshold speed whereat the combustion engine 20 progressively delivers more power relative to the electric machine 70; at the end of the phase P1, motive power to accelerate the vehicle is provided substantially from the combustion engine 20. During the phase P2, a gear change occurs wherein the electric machine 70 is again used at the commencement of the phase P3 to provide motive force in cooperation with the electric machine 70 with the combustion engine 20 again assuming a function of delivering most motive power at an end of the phase P3 just proceeding a gear change in the phase P4. At the commencement of the phase P5, the combustion engine 20 delivers relatively more motive power than the electric machine 70; during the phase P5, the combustion engine 20 increasingly delivers more motive power as power delivered from the electric machine 70 is progressively decreased. Beyond the phase P5, the combustion engine 20 is progressively more used to provide motive power to an extent that the electric machine 70 has a relatively subordinate contribution. Gear changes at the phases P2 and P4 gives rise to abrupt changes in acceleration denoted by 500 and 510 respectively which can be felt as acceleration jerks by passengers traveling in the vehicle, for example a bus.

The inventor has appreciated that operation of the hybrid powertrain 10 can be improved to provide a more uniform and smooth acceleration than that illustrated in Figure 2. The hybrid powertrain 10 is beneficially operated pursuant to the present invention, namely in a manner as illustrated in Figure 3. Referring to Figure 3, there is shown a second graph indicated generally by 600. The second graph 600 includes the aforementioned abscissa axis 410 denoting a passage of time *t* from left to right. Moreover, the ordinate axis 420 of the second graph 600 includes the aforementioned first, second and third regions 440, 460 and 480 respectively. A curve 630 in the first region 440 of the second graph 600 represents speed of the vehicle including the hybrid powertrain 10. A curve 640 of the second graph 600 corresponds to motive power provided from the electric machine 70. A curve 650 of the second graph 600 corresponds to motive power provided from the engine 20. The second graph 600 corresponds to the vehicle accelerating progressively from a phase Q1 to a phase Q5. Phases Q2 and Q4 correspond to gear changes occurring in the gearbox 200. However, in comparison to the first graph 400 of Figure 2, the second graph 600 of Figure 3 shows from the curve 630 a greater attainable vehicle speed for each gear during the phases Q1, Q3 and Q5, thereby requiring relatively less frequent gear changes, hence saving wear of the gearbox 200 and the clutch 50 and providing a smoother and more uniform acceleration than provided in the first graph 400. Thus, in the second graph 600, a greater speed range is achievable in the phases Q1, Q3 and Q5 by exploiting a characteristic that the electric machine 70 is susceptible to function over a greater rotation rate range in comparison to the combustion engine 20. Indeed, for thermal operating efficiency optimization, the combustion engine 20 optionally has a reduced rotation rate range than a conventional combustion engine not intended for use in a hybrid powertrain. If necessary, the electric machine 70 is optionally upgraded to a more powerful unit when operating pursuant to Figure 3. Thus, an important feature in Figure 3 is that the excitation to the electric machine 70 is increased substantially prior to a gear change so as to extend the phases Q3, Q5 and especially Q1. In consequence, as denoted by the curve 650, the combustion engine 20 is operable to deliver most power substantially in a middle portion of the phases Q1, Q3 and Q5. To avoid over-revving the combustion engine 20, the clutch 50 is disengaged to isolate the combustion engine 20 at latter portions of the phases Q1, Q3 and Q5, in which case motive power to accelerate the vehicle is derived solely from the electric machine 70 immediately prior to a gear change. Such a mode of operation is in contradistinction to conventional practice wherein the combustion engine 20 is regarded as being most appropriate for delivering motive power at latter regions of the phases P1, P3 and P5 just prior to gear changes as illustrated in Figure 2. Whilst the clutch 50 is used to isolate the combustion engine 20, the combustion engine 20 can optionally be deactivated; alternatively, the combustion engine 20 can be maintained active when isolated by the clutch 50.

Thus in Figure 3, the electric machine 70 provides a majority of motive power at initial start and around gear changes, whereas the engine 20 is employed to provide most motive power in intermediate regions between gear changes. Although Figure 3 illustrates acceleration of the vehicle, a similar approach can also be adopted when decelerating the vehicle to reduce a number of gear changes involved; during deceleration, the combustion engine 20 remains decoupled during intermediate regions of gear settings. For example, in an urban stop-start situation, it is feasible for the vehicle configured pursuant to the present invention to be operated solely in the phase Q1 without a gear change being necessary; in comparison, operating the vehicle according to the first graph 400 would require a gear change in the phase P2 to be required cause the phase P3 to be invoked, the gear change at the phase P2 causing a momentary interruption of motive power for the vehicle and hence acceleration jerks felt by passengers of the vehicle. Operating the powertrain 10 pursuant to the second graph 600 results in less disturbance at regions 700, 710 associated with gear changes at the phases Q2 and Q4 respectively.

Operation of the vehicle including the powertrain 10 in a manner depicted in Figure 3 is achieved by appropriately programming the central control unit 300. In particular, when the central control unit 300 is implemented as computing hardware operable to execute software, the powertrain 10 is optionally configurable to be selectively switchable between the graphs 400, 600 or any intermediate characteristic therebetween. For example, the central control unit 300 could be programmed in such a way that the operation of the hybrid powertrain implemented in a truck or bus or any other vehicle is switchable between an "urban driving" setting using the method according to the invention and a "conventional mode" setting (for instance used when driving the vehicle on the motor highway). However, the graph 600 represents an improved situation for achieving a smoother and more uniform acceleration in the vehicle.

Although the present invention has been described in the foregoing in respect of the powertrain 10, it will be appreciated that the present invention is not limited to use in such a configuration and can be adapted for use with other configurations of powertrain. Modifications to embodiments of the invention described in the foregoing are thus possible without departing from the scope of the invention as defined by the accompanying claims.

Although use of the powertrain 10 has been described in the foregoing in respect of vehicles, for example buses and trucks, it will be appreciated that it can be employed also in other types of systems, for example passenger vehicles, trams, trains, boats, ships and stationary power-delivery systems.

Expressions such as "including", "comprising", "incorporating", "consisting of", "have", "is" used to describe and claim the present invention are intended to be construed in a non-exclusive manner, namely allowing for items, components or elements not explicitly described also to be present. Reference to the singular is also to be construed to relate to the plural.

Numerals included within parentheses in the accompanying claims are intended to assist understanding of the claims and should not be construed in any way to limit subject matter claimed by these claims.

CLAIMS

1. A hybrid powertrain (10) including:

- a combustion engine (20) operable to output rotational power thereat;
- an electric machine arrangement (60), operable to output rotational power thereat;
- a gearbox arrangement (200) for receiving rotational power from at least one of the combustion engine (20) and the electric machine arrangement (60), the gearbox arrangement (200) being operable to couple corresponding motive power to a load (230);
- wherein the gearbox arrangement (200) is operable to provide a plurality of gearing ratios; and
- wherein the electric machine arrangement (60) is employable to extend a rotation rate range provided in a given gearing ratio:
  - (a) at higher rotation rates prior to a gear change from said given gearing ratio to a gearing ratio subsequent thereto; or
  - (b) at both lower rotation rates when accelerating from a standstill or from a preceding gear, and at higher rotation rates prior to a gear change from said given gearing ratio to a gearing ratio subsequent thereto.

2. A powertrain (10) as claimed in claim 1, wherein a coupling arrangement (50) included in the powertrain (10) is operable to at least partially decouple the combustion engine (20) from the gearbox arrangement (200) at said higher rotation rates.

3. A powertrain (10) as claimed in claim 2, wherein the coupling arrangement (50) is operable to fully decouple the combustion engine (20) from the gearbox arrangement (200) at said higher rotation rates.

4. A powertrain (10) as claimed in claim 1, wherein the combustion engine (20) is operable in each of the gearing ratios to deliver its maximum power at substantially a middle portion of the rotation range of the gearing ratio, with the electric machine arrangement (60) providing its maximum towards lower and upper rotation rate limits of the gearing ratio.

5. A method of controlling a hybrid powertrain (10) including:

- a combustion engine (20) operable to output rotational power thereat;
- an electric machine arrangement (60) operable to output rotational power thereat;

- a gearbox arrangement (200) for receiving rotational power from at least one of the combustion engine (20) and the electric machine arrangement (60), the gearbox arrangement (200) being operable to couple corresponding motive power to a load (230);
- wherein the gearbox arrangement (200) is operable to provide a plurality of gearing ratios,

the method including steps of:

(a) employing the electric machine arrangement (60) to extend a rotation rate range provided in a given gearing ratio at lower rotation rates when accelerating from a standstill or a preceding gearing ratio, and to extend a rotation rate range provided in the given gearing ratio at higher rotation rates prior to a gear change from said given gearing ratio to a gearing ratio subsequent thereto; or

(b) employing the electric machine arrangement (60) to extend a rotation rate range provided in the given gearing ratio at higher rotation rates prior to a gear change from said given gearing ratio to a gearing ratio subsequent thereto.

6. A method as claimed in claim 5, including a step of using a coupling arrangement (50) to at least partially decouple the combustion engine (20) from the gearbox arrangement (200) at said higher rotation rates.

7. A method as claimed claim 6, wherein the coupling arrangement (50) is operable to fully decouple the combustion engine (20) from the gearbox arrangement (200) at said higher rotation rates.

8. A method as claimed in claim 4, wherein the combustion engine (20) is operable in each of the gearing ratios to deliver its maximum power at substantially a middle portion of the rotation range of the gearing ratio, with the electric machine arrangement (60) providing its maximum towards lower and upper rotation rate limits of the gearing ratio.

9. A system including a hybrid powertrain (10) as claimed in any one of claims 1 to 4.

10. A system as claimed in claim 9, said system being operable to control its hybrid powertrain (10) using a method as claimed in any one of claims 5 to 8.

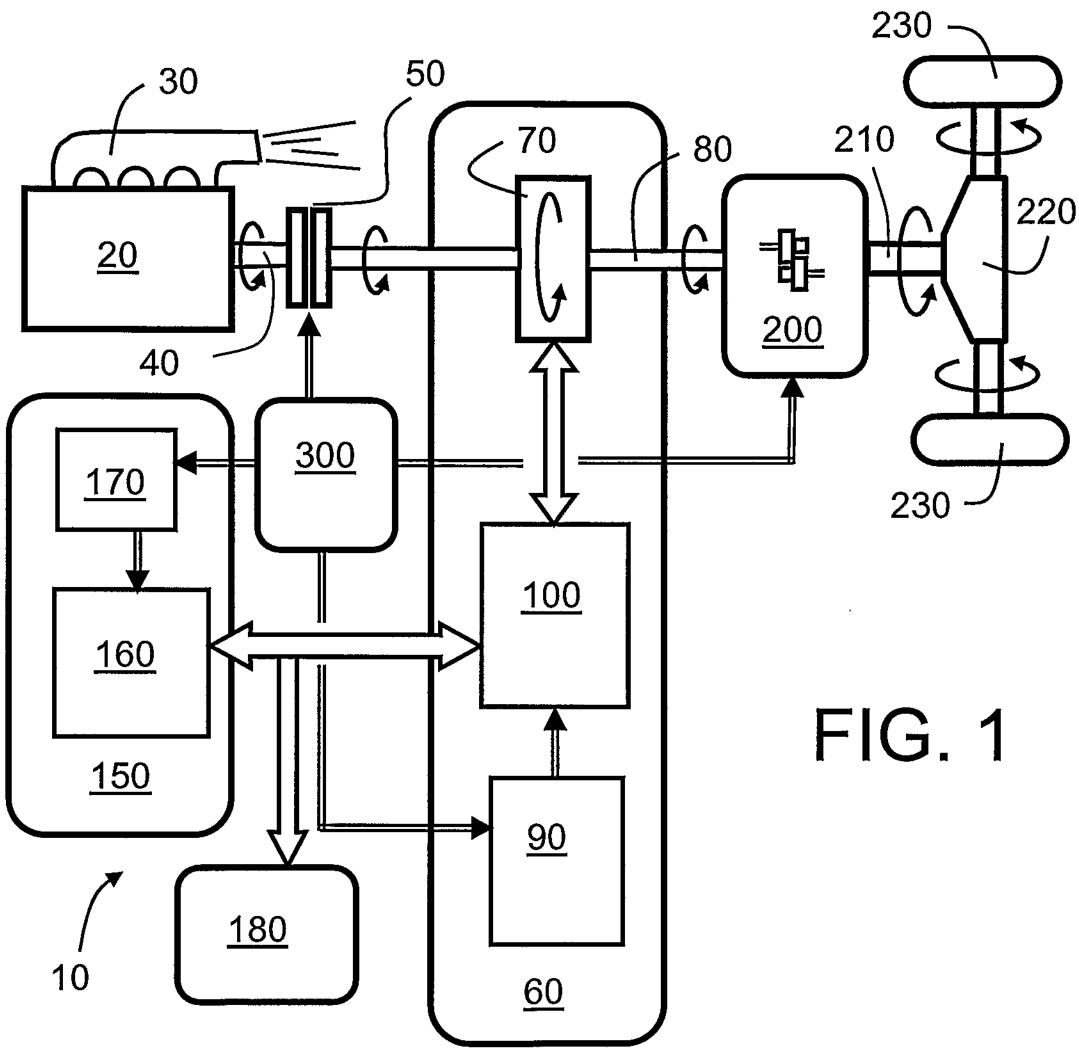
11. A system as claimed in claim 9 or 10, wherein said system is a bus, a truck, a van, a passenger vehicle, a tram, a train, a boat, a ship, or a stationary power-delivering device.

12. A computer product executable on computing hardware for implementing a method as claimed in any one of claims 5 to 8.

13. A computer product comprising computer program code means adapted to perform a method or for use in a method according to at least one of the claims 5 to 8 when said computer program is run on a programmable microcomputer.

14. A computer program according to claim 13 adapted to be downloaded to a powertrain according to claim 1 or one or more of its components when run on a computer which is connected to the Internet.

15. A computer program product stored on a computer readable medium, comprising computer program code means according to claim 13.


230
30
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210
220
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170
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180
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230

FIG. 1

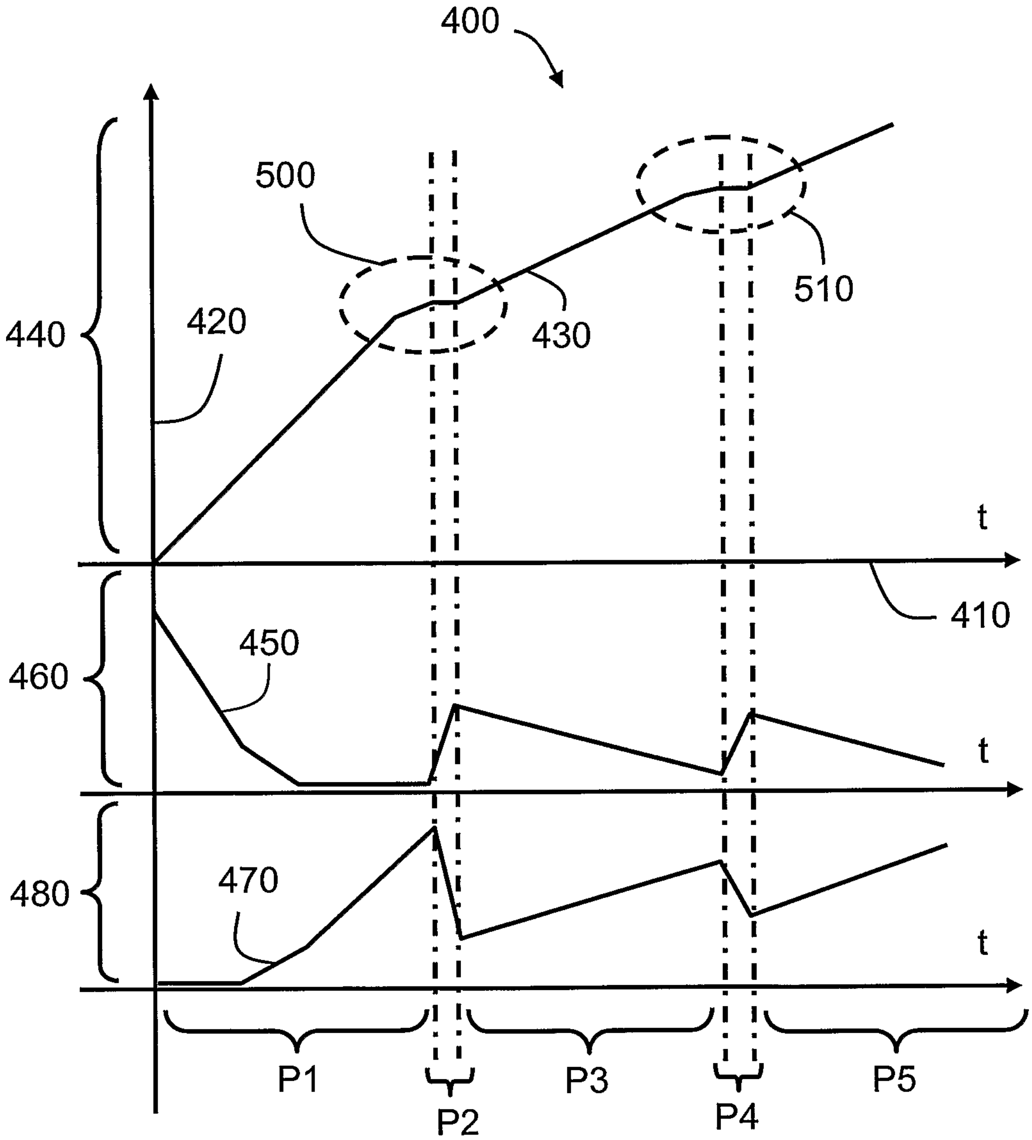

FIG. 2

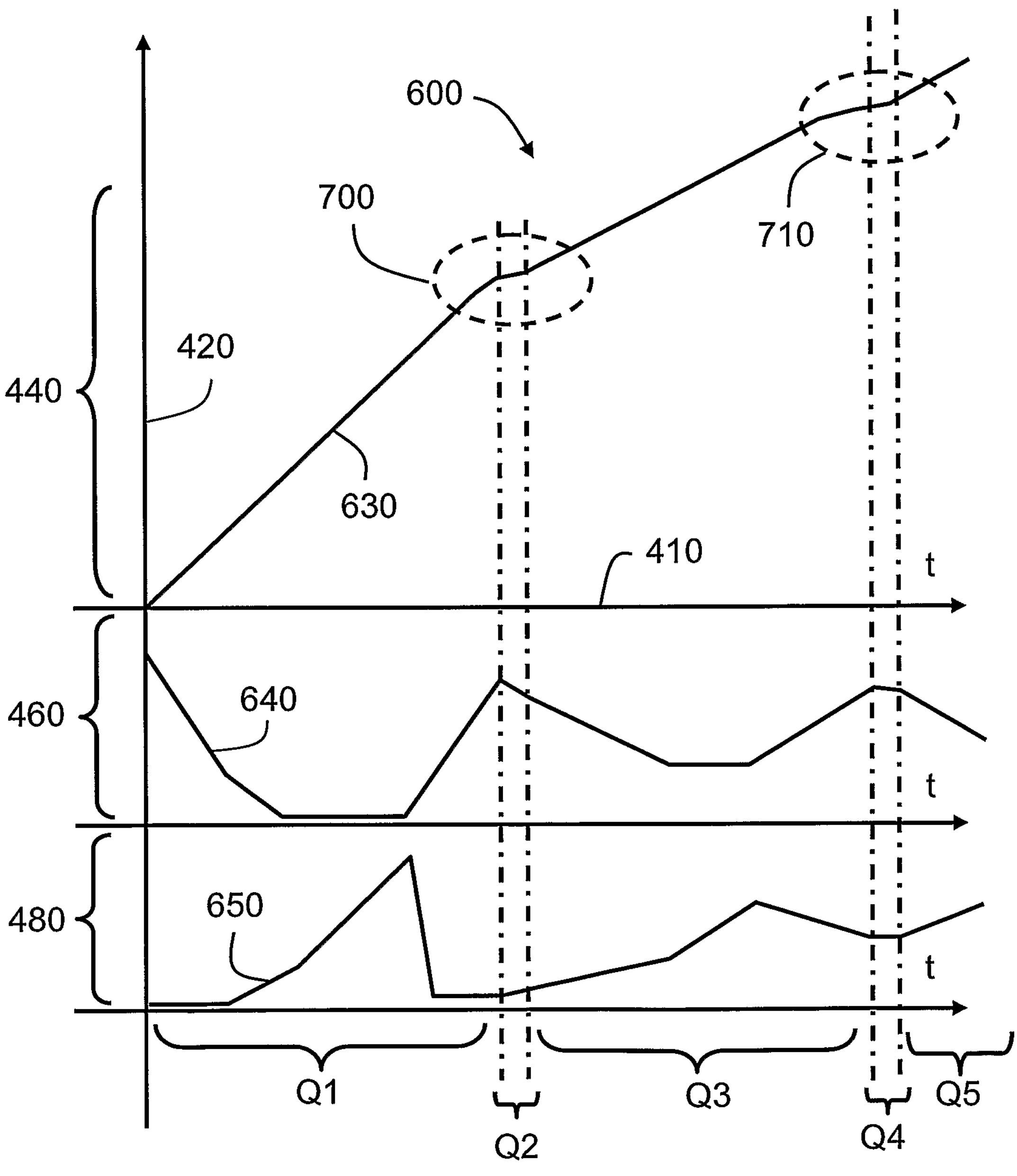

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2006/000315

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B60K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2005016681 A1 (DAIMLERCHRYSLER AG), 24 February 2005 (24.02.2005) --	1-13,15
A	WO 9715979 A1 (ROBERT BOSCH GMBH), 1 May 1997 (01.05.1997) --	1-13,15
A	US 5713425 A (BUSCHHAUS ET AL), 3 February 1998 (03.02.1998) -- --------	1-13,15

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 October 2006	17-10-2006
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Erik Wiss/EK Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2006/000315

International patent classification (IPC)
B60K 6/02 (2006.01)

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Cited literature, if any, will be enclosed in paper form.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SE2006/000315

WO	2005016681	A1	24/02/2005	DE	10335421	A	17/02/2005
WO	9715979	A1	01/05/1997	DE	19539571	A,C	30/04/1997
				EP	0857371	A	12/08/1998
				JP	11513878	T	24/11/1999
US	5713425	A	03/02/1998	NONE			