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(71) Applicant: **CUMMINS INC.** [US/US]; 500 Jackson Street, Columbus, IN 47201 (US).

(72) Inventors: **BOOKS, Martin, T.**; 208 19th Street, Columbus, IN 47201 (US). **FRANCO, Javier**; 14869 Peach Meadow Lane, Channel View, TX 77530 (US). **MURALIDHAR, Praveen, Chitradurga**; 7128 Chesterton Lane, Indianapolis, IN 46237 (US).

(74) Agent: **NULL, Robert, D.**; Faegre Baker Daniels LLP, 300 North Meridian Street, Suite 2700, Indianapolis, IN 46204 (US).

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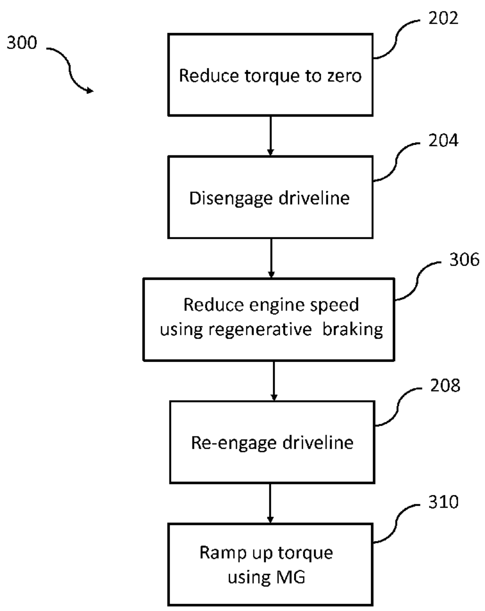

FIGURE 3

(57) Abstract: A system and method are disclosed for controlling shifting of a hybrid vehicle having an automated manual transmission. According to one embodiment, the disclosure provides a method for controlling upshifting of a hybrid vehicle having an automated manual transmission, comprising disengaging a driveline of the vehicle, activating a motor/generator of the vehicle to provide regenerative braking to reduce engine speed in response to disengaging the driveline, and re-engaging the driveline.

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HYBRID MOTOR ASSIST OF GEAR SHIFTING

RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. Provisional Application No. 62/000,686, entitled "Hybrid Motor Assist of Gear Shifting," filed on May 20, 2014, the entire disclosure of which being hereby expressly incorporated herein by reference.

FIELD OF THE DISCLOSURE

[0002] The present disclosure generally relates to hybrid vehicles, and more specifically to use of regenerative braking to assist shifting of hybrid vehicles having automated manual transmissions.

BACKGROUND OF THE DISCLOSURE

[0003] Hybrid vehicles possess certain capabilities that are not present in either fully conventional vehicles (i.e., internal combustion engine ("ICE") powered vehicles) or fully electric vehicles (i.e., electric motor/generator ("MG") and battery powered vehicles). Hybrid vehicles have greater range than electric vehicles, and are capable of distances similar to ICE powered vehicles. Hybrid vehicles also have superior transient response relative to ICE powered vehicles, with much more rapid torque generating capabilities since they lack the lags associated with fresh air delivery and even with fuel delivery. Typically, this improved transient response is not used to produce a higher performance vehicle because a primary justification for the added expense of a hybrid vehicle is improved fuel economy, not better performance.

[0004] In many commercial vehicles equipped with an Automated Manual Transmission (AMT), gear shifts can be a challenging transient. In an AMT, the execution of an upshift (shift to the next higher gear, resulting in a net decrease in engine speed) or a downshift (shift to the next lower gear, resulting in a net increase in engine speed) is often paced by the transient response of the engine. While significant increases in fuel may be provided to quickly accelerate the engine to a higher speed needed for a downshift, in an upshift the engine fuel can only be reduced to zero, and deceleration is dictated by engine friction. This deceleration rate can often cause shift times to be in excess of one second. When the driver is attempting to accelerate the vehicle hard, a one second interruption in engine torque can feel very significant. Moreover, attempts to improve engine efficiency often involve reductions in engine friction, which results in even longer deceleration rates.

[0005] One approach to providing improved engine deceleration during AMT upshifting is the use of engine braking, either exhaust or compression. While this approach may achieve quicker deceleration during upshifts, the shift quality (i.e., torque ramp up) is dictated by the engine’s transient response, and engine braking has no application to downshifting.

[0006] Accordingly, for hybrid vehicles with AMT, it is desirable to provide reduced deceleration times during upshifting. It is further desirable to control torque ramp up to improve shift quality, and enhance engine acceleration during downshifting.

SUMMARY

[0007] According to one embodiment, the disclosure provides a method for controlling upshifting of a hybrid vehicle having an automated manual transmission, comprising disengaging a driveline of the vehicle, activating a motor/generator of the vehicle to provide regenerative braking to reduce engine speed in response to disengaging the driveline, and re-engaging the driveline. One aspect of this embodiment further comprising storing energy collected during the regenerative braking in at least one electrical energy storage device. In a variant of this aspect, the at least one electrical energy storage device is a battery. Another aspect further comprises activating the motor/generator to ramp up torque at the driveline in response to re-engaging the driveline. A variant of this aspect comprises activating the motor/generator to ramp up torque at the driveline in response to re-engaging the driveline and controlling the activating the motor/generator to ramp up torque to use the energy collected during the regenerative braking to result in a state-of-charge neutrality of the at least one electrical energy storage device.

[0008] In another embodiment, the present disclosure provides a method for controlling downshifting of a hybrid vehicle having an automated manual transmission, comprising disengaging a driveline of the vehicle, activating a motor/generator of the vehicle to increase engine speed in response to disengaging the driveline, and re-engaging the driveline. One aspect of this embodiment further comprises activating the motor/generator to ramp up torque at the driveline in response to re-engaging the driveline.

[0009] In yet another embodiment, the present disclosure provides a hybrid vehicle comprising an engine, a transmission coupled to a driveline and to the engine, a motor/generator coupled to the transmission and to the engine, the motor/generator being configured to engage the engine to provide regenerative braking of the engine, wherein the motor/generator removes energy from a powertrain of the vehicle and to engage the transmission to provide increased torque to the driveline, wherein the motor/generator contributes energy to the powertrain, and a controller in communication with the engine, the transmission and the motor/generator, the controller controlling an upshift of the transmission by reducing torque delivered by the engine to zero, causing the driveline to disengage from the powertrain, activating the motor/generator to provide regenerative braking to reduce engine speed, and causing the driveline to re-engage the powertrain in response to engine speed being reduced. One aspect of this embodiment further includes at least one electrical energy storage device, the motor/generator being configured to store the energy removed from the powertrain during regenerative braking in the at least one electrical energy storage device. In a variant of this aspect, the electrical energy storage device is a battery. In another variant, the controller further controls the upshift by activating the motor/generator to provide increased torque to the powertrain in response to the driveline re-engaging the powertrain, the increased torque corresponding to an amount of energy contributed to the powertrain that results in a state-of-charge neutrality of the at least one electrical energy storage device. In another aspect of this embodiment, the controller further controls the upshift by activating the motor/generator to provide increased torque to the powertrain in response to the driveline re-engaging the powertrain. In another aspect, the controller further controls a downshift of the transmission by reducing torque delivered by the engine to zero, causing the driveline to disengage from the powertrain, activating the motor/generator to increase engine speed in response to disengaging the driveline, and causing the driveline to re-engage the powertrain in response to engine speed being increased. In a variant of this aspect, the controller further controls the downshift by activating the motor/generator to provide increased torque to the powertrain in response to the driveline re-engaging the powertrain.

[0010] In still another embodiment, the present disclosure provides a controller comprising a processor, and a memory having instructions which, when executed by the processor cause the controller to control an upshift of a transmission of a vehicle by reducing torque delivered by an engine of the vehicle to zero, causing a driveline of the vehicle to disengage from a powertrain of the vehicle, activating a motor/generator of the vehicle to provide regenerative braking to reduce engine speed, and causing the driveline to re-engage the powertrain in response to the engine speed being reduced. In one aspect of this embodiment, the instructions when executed by the processor further cause the controller to control the upshift by activating the motor/generator to provide increased torque to the powertrain in response to the driveline re-engaging the powertrain. In another aspect the instructions when executed by the processor further cause the controller to control a downshift of the transmission by reducing torque delivered by the engine to zero, causing the driveline to disengage from the powertrain, activating the motor/generator to increase engine speed in response to disengaging the driveline, and causing the driveline to re-engage the powertrain in response to engine speed being increased. In a variant of this aspect the controller further controls the downshift by activating the motor/generator to provide increased torque to the powertrain in response to the driveline re-engaging the powertrain.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The above-mentioned and other features and advantages of this disclosure, and the manner of attaining them, will become more apparent and the invention itself will be better understood by reference to the following description of embodiments of the invention taken in conjunction with the accompanying drawings, wherein:

[0012] FIG. 1 is a schematic diagram of a hybrid vehicle;

[0013] FIG. 2 is a flowchart of a prior method of controlling shifting;

[0014] FIG. 3 is a flowchart of a method of controlling shifting according to one embodiment of the present disclosure; and

[0015] FIG. 4 is a flowchart of another method of controlling shifting according to another embodiment of the present disclosure.

[0016] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate exemplary embodiments of the invention and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DETAILED DESCRIPTION

[0017] Referring initially to FIG. 1, a system 10 is shown for facilitating shifting on a hybrid vehicle with AMT. System 10 includes a vehicle 12 which has a powertrain 14. Powertrain 14 includes an internal combustion engine 16 coupled to a generator 18. Engine 16 and generator 18 are coupled to a transmission 20, which is coupled to drive a driveline 22. In some applications, engine 16 is a diesel engine. In one embodiment of the disclosure, generator 18 is a motor/generator (referred to hereinafter as MG 18) as is common in hybrid vehicle applications. An electrical energy storage device 24 is electrically connected to MG 18 to store electricity generated by MG 18 . Electrical energy storage device 24 can be a battery such as a lithium ion battery, a lead-acid battery, a nickel metal hydride battery, or any other device capable of storing electrical energy.

[0018] In certain embodiments, system 10 further includes a controller 26 to perform certain operations to control engine 16 and the operation of MG 18, particularly during upshifting and downshifting as is further described below. In certain embodiments, controller 26 forms a portion of a processing subsystem including one or more computing devices having memory, processing, and communication hardware. Controller 26 may be a single device or a distributed device, and the functions of controller 26 may be performed by hardware and/or software instructions stored in the memory or elsewhere.

[0019] FIG. 2 depicts an overview of a prior art method of executing an upshift on a vehicle 12 with AMT. The steps of method 200 generally mimic the actions of a driver executing a similar upshift using a manual transmission. As shown, in step 202 torque is reduced to zero. Generally, this step is performed to either unload driveline 22 to allow transmission 20 to disengage without the aid of a slipping clutch, or to avoid the jarring sensation of a torque discontinuity as driveline 22 is disengaged with or without a slipping clutch. At the end of step 202, engine 16 will be performing no work, and engine fueling is consequently equal to only that fueling required to overcome the engine's own internal friction. This level of fueling is relatively low in comparison to the engine's fueling range.

[0020] At step 204, driveline 22 is actually disengaged. If engine fueling (and torque) has been ramped down to the correct value during step 202, then disengaging the vehicle driveline 22 from engine 16 at step 204 will have minimal impact on engine speed.

[0021] Next, at step 206, the engine speed is reduced to a value consistent with current vehicle speed and the desired next gear. For many vehicles, this will require anywhere from a 15% to a 30% drop in engine rpm. As engine fueling has already been significantly reduced at step 202 to facilitate driveline 22 disengagement at step 204, there is very little engine controller 26 can do to affect a more rapid deceleration. Fueling can only be dropped to zero, at which point engine friction plus accessory loads are all that contribute decelerating forces. Accordingly, step 206 is often the pacing factor in resulting shift times. As indicated above, engine braking (e.g., compression braking or exhaust braking) may be employed in an effort to improve engine deceleration. However, the actuation times of typical engine brake hardware renders this approach to be of minimal value.

[0022] Next, at step 208, when engine speed has reached the new target, driveline 22 is re-engaged. Finally, at step 210, torque is ramped up to the level determined by the driver.

[0023] As is known to those skilled in the art, method 200 of FIG. 2 involves a compromise of swiftness and smoothness. There are things that could be done to speed up the process, but those changes may make the upshift feel harsh to the driver. Alternately, there are things that could be done to make the upshift feel smoother to the driver, but those changes may result in an excessive overall shift time. The two steps that are most relevant to this trade-off are step 206 and step 210. Step 206 is relevant because of the difficulty in enhancing the deceleration rate of engine 16. Step 210 is relevant because the smooth recovery of the driver's commanded torque is the phase that the driver is most likely to feel. The present disclosure addresses both of these issues for hybrid vehicles.

[0024] During step 206, the desire is to reduce engine speed and, thus, engine kinetic energy in preparation for re-engaging driveline 22 at step 208. The power plants of hybrid vehicles provide a very effective method of absorbing kinetic energy -- regenerative braking. Referring now to FIG. 3, a method 300 according to the present disclosure is shown including use of regenerative braking. As shown, steps 202 and 204 of FIG. 3 are the same as those of FIG. 2. Step 206 is replaced, however, with step 306, which accomplishes engine speed reduction using regenerative braking. Use of regenerative braking to decelerate engine 16 at step 306 provides a faster response time than possible using reduced fueling and engine friction, thereby resulting in a shorter upshift event. Additionally, such use of regenerative braking permits collection of engine kinetic energy, resulting in additional energy for electrical energy storage device 24 and improved fuel economy. Moreover, the precision with which negative torque can be commanded and controlled through regenerative braking using MG 18 is greater than the precision of torque control using friction alone or engine braking. As such, use of regenerative braking may provide higher quality speed transients, reaching the target speed faster and with less undershoot than in a conventional system. Consequently, use of regenerative braking at step 306 permits use of a hybrid power plant to both improve performance while not sacrificing (or perhaps even improving) fuel economy.

[0025] Still referring to FIG. 3, step 208 is the same as that shown in FIG. 2. Step 210, however, is replaced with step 310. At step 310, the torque ramp up includes use of MG 18 to achieve a desired trajectory. MG 18 may be employed as either a partial contributor or the sole contributor of driveline 22 torque during ramp up. This permits more precise and rapid torque control. Furthermore, while in step 206 MG 18 collected net energy from powertrain 14, in step 310 MG 18 contributes net energy to powertrain 14.

The implementation of these steps may be controlled by controller 26 for example to result in State-of-Charge ("SOC") neutrality of electrical energy storage device 24. Moreover, use of MG 18 as a powertrain contributor during step 310 (as opposed to or in conjunction with engine 16 of hybrid vehicle 12), will result in a reduction in fuel consumption.

[0026] As should be apparent from the foregoing, the use of MG 18 may further assist in downshifting events. More specifically, according to another embodiment of the disclosure depicted in FIG. 4, a method 400 is provided for controlling downshifting of hybrid vehicle 12 having an AMT. As shown, steps 202, 204 and 208 of method 400 are the same as those described above with reference to FIG. 2. Method 400 includes step 406 which involves activating MG 18 to increase engine speed after disengaging driveline 22 to reduce the time required for the overall downshifting event. Method 400 also includes step 410 wherein MG 18 is used to ramp up torque quickly after driveline 22 is re-engaged.

[0027] While this invention has been described as having exemplary designs, the present invention can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains and which fall within the limits of the appended claims.

WHAT IS CLAIMED IS:

1. A method for controlling upshifting of a hybrid vehicle having an automated manual transmission, comprising:

disengaging a driveline of the vehicle;

activating a motor/generator of the vehicle to provide regenerative braking to reduce engine speed in response to disengaging the driveline; and

re-engaging the driveline.

2. The method of claim 1, further comprising storing energy collected during the regenerative braking in at least one electrical energy storage device.

3. The method of claim 1, wherein the at least one electrical energy storage device is a battery.

4. The method of claim 1, further comprising activating the motor/generator to ramp up torque at the driveline in response to re-engaging the driveline.

5. The method of claim 2, further comprising activating the motor/generator to ramp up torque at the driveline in response to re-engaging the driveline and controlling the activating the motor/generator to ramp up torque to use the energy collected during the regenerative braking to result in a state-of-charge neutrality of the at least one electrical energy storage device.

6. A method for controlling downshifting of a hybrid vehicle having an automated manual transmission, comprising:

disengaging a driveline of the vehicle;

activating a motor/generator of the vehicle to increase engine speed in response to disengaging the driveline; and

re-engaging the driveline.

7. The method of claim 6, further comprising activating the motor/generator to ramp up torque at the driveline in response to re-engaging the driveline.

8. A hybrid vehicle comprising:

an engine;

a transmission coupled to a driveline and to the engine;

a motor/generator coupled to the transmission and to the engine, the motor/generator being configured to engage the engine to provide regenerative braking of the engine, wherein the motor/generator removes energy from a powertrain of the vehicle and to engage the transmission to provide increased torque to the driveline, wherein the motor/generator contributes energy to the powertrain; and

a controller in communication with the engine, the transmission and the motor/generator, the controller controlling an upshift of the transmission by reducing torque delivered by the engine to zero, causing the driveline to disengage from the powertrain, activating the motor/generator to provide regenerative braking to reduce engine speed, and causing the driveline to re-engage the powertrain in response to engine speed being reduced.

9. The hybrid vehicle of claim 8, further including at least one electrical energy storage device, the motor/generator being configured to store the energy removed from the powertrain during regenerative braking in the at least one electrical energy storage device.

10. The hybrid vehicle of claim 9, wherein the electrical energy storage device is a battery.

11. The hybrid vehicle of claim 9, wherein the controller further controls the upshift by activating the motor/generator to provide increased torque to the powertrain in response to the driveline re-engaging the powertrain, the increased torque corresponding to an amount of energy contributed to the powertrain that results in a state-of-charge neutrality of the at least one electrical energy storage device.

12. The hybrid vehicle of claim 8, wherein the controller further controls the upshift by activating the motor/generator to provide increased torque to the powertrain in response to the driveline re-engaging the powertrain.

13. The hybrid vehicle of claim 8, wherein the controller further controls a downshift of the transmission by reducing torque delivered by the engine to zero, causing the driveline to disengage from the powertrain, activating the motor/generator to increase engine speed in response to disengaging the driveline, and causing the driveline to re-engage the powertrain in response to engine speed being increased.

14. The hybrid vehicle of claim 13, wherein the controller further controls the downshift by activating the motor/generator to provide increased torque to the powertrain in response to the driveline re-engaging the powertrain.

15. A controller comprising:

a processor; and

a memory having instructions which, when executed by the processor cause the controller to control an upshift of a transmission of a vehicle by reducing torque delivered by an engine of the vehicle to zero, causing a driveline of the vehicle to disengage from a powertrain of the vehicle, activating a motor/generator of the vehicle to provide regenerative braking to reduce engine speed, and causing the driveline to re-engage the powertrain in response to the engine speed being reduced.

16. The controller of claim 15, wherein the instructions when executed by the processor further cause the controller to control the upshift by activating the motor/generator to provide increased torque to the powertrain in response to the driveline re-engaging the powertrain.

17. The controller of claim 15, wherein the instructions when executed by the processor further cause the controller to control a downshift of the transmission by reducing torque delivered by the engine to zero, causing the driveline to disengage from the powertrain, activating the motor/generator to increase engine speed in response to disengaging the driveline, and causing the driveline to re-engage the powertrain in response to engine speed being increased.

18. The controller of claim 17, wherein the controller further controls the downshift by activating the motor/generator to provide increased torque to the powertrain in response to the driveline re-engaging the powertrain.

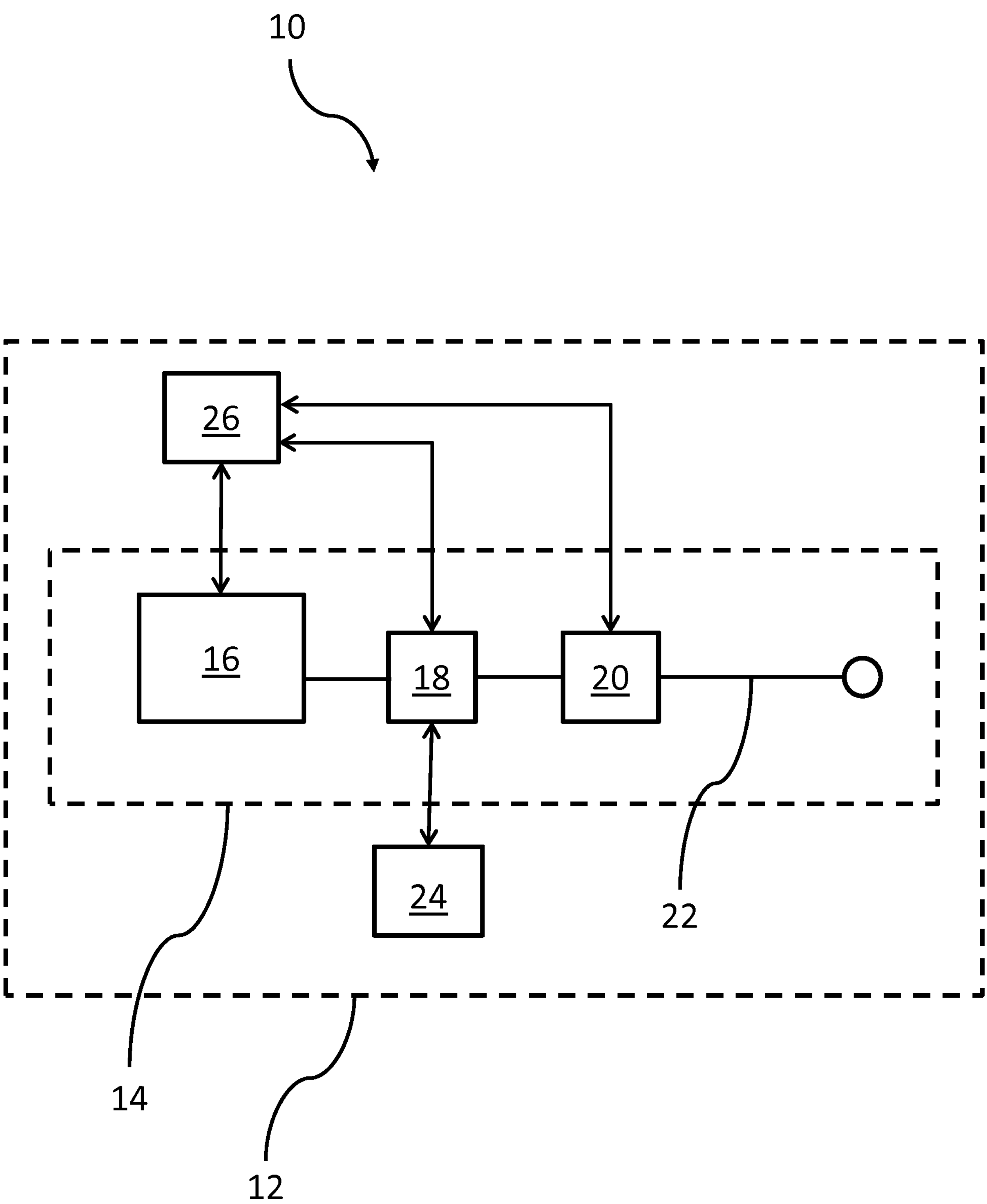

FIGURE 1

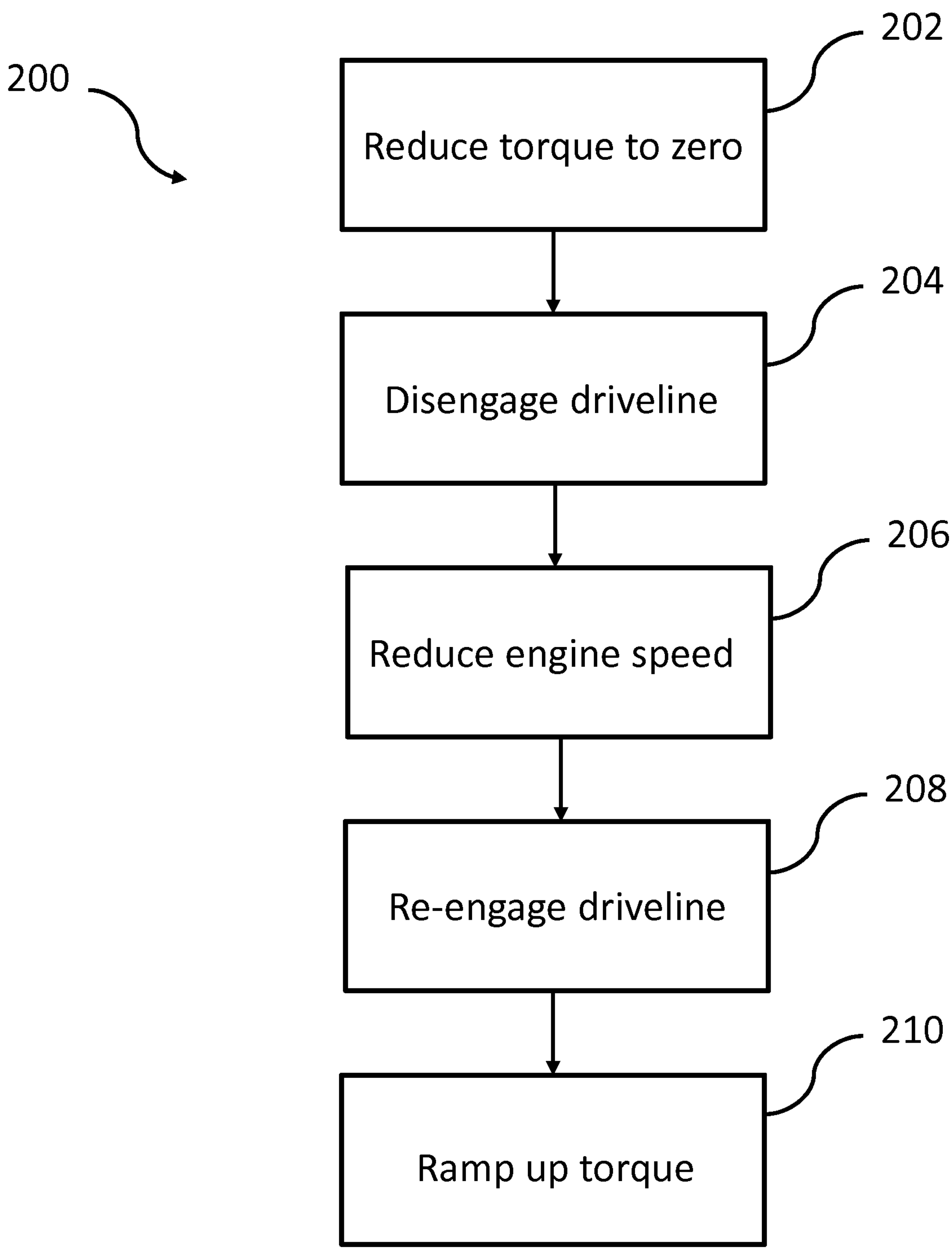

FIGURE 2 – Prior Art

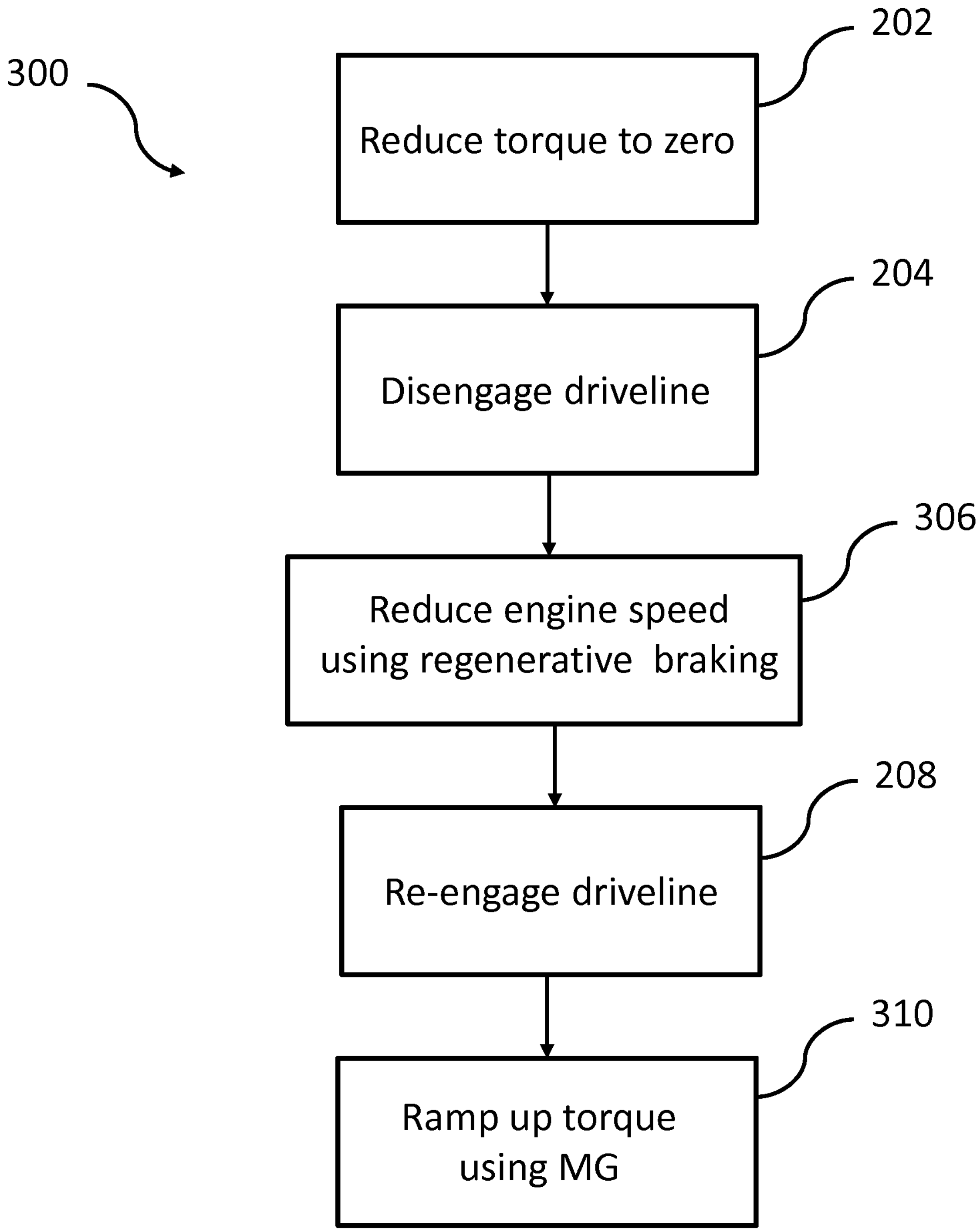
300
202
Reduce torque to zero
204
Disengage driveline
306
Reduce engine speed using regenerative braking
208
Re-engage driveline
310
Ramp up torque using MG

FIGURE 3

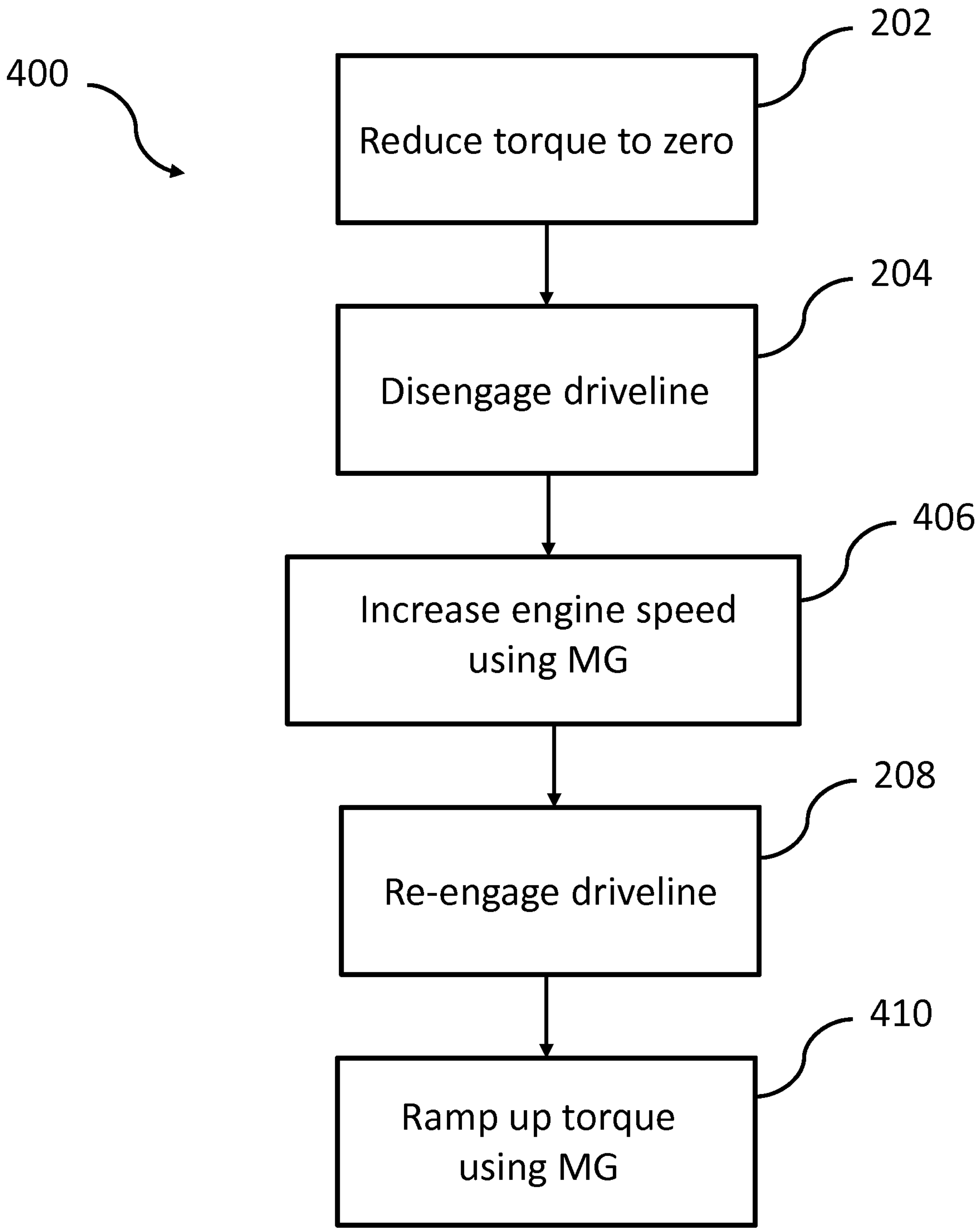
400
202
Reduce torque to zero
204
Disengage driveline
406
Increase engine speed using MG
208
Re-engage driveline
410
Ramp up torque using MG

FIGURE 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/031715

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B60W 10/00 (2015.01)
CPC - B60W 10/00 (2015.07)
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(8) - B60W 10/00, 10/02, 10/10 (2015.01)
CPC - B60W 10/00, 10/02, 10/10 (2015.07)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 74/640; 180/65.21, 65.22, 65.27, 65.275, 65.285; 192/3.51; 322/28; 477/3, 4, 5, 34; 701/1, 22, 51, 53, 67; 903/902, 903, 917, 919, 945, 946, 947 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Google Scholar, Google, YouTube.
Search terms used: manual, transmission, automated, regenerate, brake, upshift, downshift, dual, clutch, generator, alternator, hybrid, ramp, torque, speed, RPM, reduce, decrease, zero

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,319,167 B1 (YOSHIDA et al) 20 November 2001 (20.11.2001) entire document	1-18
A	US 2008/0314663 A1 (YAMAZAKI et al) 25 December 2008 (25.12.2008) entire document	1-18
A	US 2009/0149295 A1 (YAMAMOTO et al) 11 June 2009 (11.06.2009) entire document	1-18
A	US 2008/0306643 A1 (HANYU et al) 11 December 2008 (11.12.2008) entire document	1-18

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 July 2015	14 AUG 2015

Name and mailing address of the ISA/	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Blaine Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774