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(71) Applicant *(for all designated States except US)*: **CHRYSLER LLC** [US/US]; 1000 Chrysler Drive, Auburn Hills, MI 48326-2766 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **KRUPADANAM, Ashish** [US/US]; 10281 Bonny Drive, Cupertino, CA 95014 (US). **PATEL, Nadirsh** [IN/US]; 29523 Shenandoah Drive, Farmington Hill, MI 48331 (US). **TAMAI, Goro** [US/US]; 7532 Glascott Avenue, West Bloomfield, MI 48323 (US).

(74) Agent: **MINUTOLI, Gianni**; Dickstein Shapiro LLP, 1825 Eye Street, NW, Washington, DC 20006-5403 (US).

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(54) Title: MODE SELECTION CONTROL SYSTEM FOR AN ELECTRICALLY VARIABLE TRANSMISSION

(57) Abstract:

MODE SELECTION CONTROL SYSTEM FOR AN ELECTRICALLY VARIABLE TRANSMISSION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 61/513,080, filed July 29, 2011.

FIELD

[0002] The present disclosure relates to the control of an automotive transmission, specifically to a mode selection control system and method for controlling an electrically variable transmission.

BACKGROUND

[0003] Some current hybrid electrically variable transmissions feature two electric motors coupled to an internal combustion engine utilizing a plurality of clutches and gear sets. At certain times it is desirable to operate the transmissions in strictly an electric mode or in a hybrid mode where the internal combustion engine and one or both motors operate simultaneously. Managing the many parameters such as clutch, engine and motor torques, battery power levels and usage, efficiency and smooth shifting between the various gears and drive modes, fuel economy, operational-cost efficiency, etc. pose many operational control challenges.

[0004] Thus, there remains a need for continuous improvement in the operational control of hybrid electrically variable transmissions.

SUMMARY

[0005] In one form, the present disclosure provides a method of selecting a mode of operation of a vehicle having an electrically variable transmission. The method comprises using a processor to perform the steps of: determining a battery discharge penalty; determining a cost associated with operating an electrical portion of the transmission; determining a cost associated with operating a mechanical portion of the transmission; calculating respective costs for operating the vehicle in a plurality of operating modes based on the battery discharge penalty and the costs associated with operating the electrical and mechanical portions of the transmission; and selecting an operating mode having the lowest calculated cost.

[0006] The present disclosure also provides a controller for selecting a mode of operation of a vehicle having an electrically variable transmission. The controller comprises a processor programmed to: determine a battery discharge penalty; determine a cost associated with operating an electrical portion of the transmission; determine a cost associated with operating a mechanical portion of the transmission; calculate respective costs for operating the vehicle in a plurality of operating modes based on the battery discharge penalty and the costs associated with operating the electrical and mechanical portions of the transmission; and select an operating mode having the lowest calculated cost.

[0007] Further areas of applicability of the present disclosure will become apparent from the detailed description, drawings and claims provided hereinafter. It should be understood that the detailed description, including

disclosed embodiments and drawings, are merely exemplary in nature intended for purposes of illustration only and are not intended to limit the scope of the invention, its application or use. Thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Figure 1 is an illustration of a lever diagram of a drive system for a vehicle with an electrically variable transmission;

[0009] Figure 2 is an illustration of an example drive cycle for a vehicle in accordance with the present disclosure;

[0010] Figure 3 is a table describing the various drive cycle points illustrated in Figure 2;

[0011] Figure 4 is a flowchart of a mode selection control process in accordance with the present disclosure;

[0012] Figure 5 is a graph of power versus time for electric vehicle operation in accordance with the present disclosure;

[0013] Figure 6 is a graph of output and engine speeds versus time for under and over drive modes of operation in accordance with the present disclosure;

[0014] Figure 7 is a graph of output, engine and main planetary torques versus time for under and over drive modes of operation in accordance with the present disclosure; and

[0015] Figure 8 is a block diagram of a portion of a vehicle's powertrain incorporating a controller for executing the methodology disclosed herein.

DETAILED DESCRIPTION

[0016] U.S. Application no. 12/882,936, (the "'936 Application) filed September 15, 2010 and titled "Multi-Speed Drive Unit," (Chrysler Attorney docket no. 708496US1) discloses various compound-input electrically variable transmissions ("EVT"), the disclosure incorporated herein by reference. U.S. Application no. 13/188,799; filed July 22, 2011and titled "Clutch System for a Transmission" (Chrysler Attorney docket no. 708578US1), the disclosure incorporated herein by reference, discloses a clutch system that can be used e.g., in the '936 Application's multi-speed drive unit to create a two dry "clutch" drive system, similar to a DDCT (dual dry clutch transmission), for the drive unit. Figure 1 is an example lever diagram of such a drive system 10.

[0017] A seen in Figure 1, the drive system 10 includes a first planetary gear set represented by a first lever L_1 and a second planetary gear set represented by a second lever L_2. A ring gear R_1 of the first planetary gear set is connected to an internal combustion engine ICE via an input shaft 12. A sun gear S_1 of the first planetary gear set is connected to two clutches CB_1, C_2. In the illustrated example, the first clutch CB_1 is a braking mechanism that, when activated, grounds the sun gear S_1 to the drive unit's transaxle case. When activated, the second clutch C_2 connects the sun gear S_1 to the engine. An input brake is created when both clutches CB_1, C_2 are activated at the same time.

[0018] The carriers of the planetary gear sets are connected via a main shaft 14. A sun gear S_2 of the second planetary gear set is connected to a first electric motor EMA. A ring gear R_2 of the second planetary gear set is connected to a second electric motor EMB via a motor speed reducer ("MSR") 16. The ring gear R_2 of the second planetary gear set is also connected to an output shaft 18. The motor speed reducer 16 controls the speed ratio between the second electric motor EMB and the output shaft 18.

[0019] The '936 Application discloses three input ratios. A first ratio is created by activating the first clutch CB_1 while deactivating the second clutch C_2. A second ratio is created by deactivating the first clutch CB_1 while activating the second clutch C_2. The third ratio is the input brake created by activating the first and second clutches CB_1, C_2. There is a need to control the drive system 10 to efficiently switch between drive modes and gear ratios to optimize the system's and vehicle's performance and to improve fuel economy.

[0020] Figure 2 is an illustration of an example drive cycle for a vehicle containing a Figure 1 drive system 10 and being controlled in accordance with the present disclosure. In the example, the vehicle accelerates from a stop, cruises at high speed and brakes to a stop. The various points and switching points of the drive cycle are listed in the table shown in Figure 3.

[0021] During the cycle, the system 10 enters different modes to deliver the required output power from the electric motors and/or engine to the output shaft. The modes are chosen for best fuel economy and drive quality. The system 10 will operate in the following modes: input brake electric vehicle ("IB-EV"), under drive electric vehicle ("UD-EV"), over drive electric vehicle ("OD-EV"), under drive engine on ("UD-EO"), over drive engine on ("OD-EO"), and neutral (N). As shown in the table of Figure 3, there are points and modes when the electric motors are propelling the vehicle without assistance from the engine (e.g., point A), propelling the vehicle with the assistance from the engine (e.g., points D to E) or providing regenerative braking (e.g., point G).

[0022] Both clutches CB_1 and C_2 will be applied (i.e., engaged or activated) to implement the IB-EV mode. The first clutch CB_1 will be applied while the second clutch C_2 is not applied (i.e., disengaged or deactivated) to implement the UD-EV and UD-EO modes. The first clutch CB_1 will not be applied while the second clutch C_2 is applied to implement the OD-EV and OD-EO modes. Both clutches CB_1 and C_2 will be disengaged in the neutral mode. It should be appreciated that this disclosure refers to the first clutch CB_1 as a braking clutch, but the disclosure is not limited to a braking clutch; as shown in the '936 application, many clutches or synchronizers could be used in the system 10.

[0023] The aspects of the present disclosure are designed to select the optimum mode of operation (i.e., IB-EV, UD-EV, OD-EV, UD-EO, OD-EO, and N) for the system. The control method described herein is implemented on a controller or programmed processor in the drive system. In one preferred implementation, the aspects described herein will be implemented as part of a supervisory hybrid electric vehicle controller 802 (Figure 8) such as the one described in U.S. application no. 61/513,061; filed July 29, 2011 and titled "Engine Start Control System for an Electrically Variable Transmission" (Chrysler Attorney docket no. 708620US1), the disclosure incorporated herein by reference. The aspects described herein will analyze the modes of operation and determine, from an over-all system point of view, which mode would be the most efficient to operate the transaxle in at any given point in time.

[0024] Figure 4 is a flowchart of a mode selection control process 400 in accordance with the present disclosure. At step 402, the process 400 uses the vehicle's speed and driver pedal position (i.e., position of the vehicle's throttle) to calculate the actual output speed N_O and a desired output torque T_O. The calculated actual output speed N_O and desired output torque T_O are used, along with an input battery state of charge ("SOC"), at step 404 to calculate a battery discharge penalty P_{Disch}. The process at step 404 also ensures that the calculated battery discharge penalty P_{Disch} is calibrated to maintain the battery within a minimum and maximum state of charge range.

[0025] Step 406 calculates the "cost" for operating the system in the IB-EV mode, which is shown as a function $f_{EV}(P_{Disch}, P_{Electrical})$. It should be noted that the term "cost" is used herein to refer to the amount of mechanical and electrical resources needed to implement the mode. $P_{Electrical}$ is the penalty/cost for operating the electric motors. As mentioned above, in the IB-EV mode, the engine is held stationary by engaging both clutches CB_1, C_2. In this mode, the vehicle is propelled only by the two electric motors EMA, EMB. Thus, the output torque is the combination of the torques from the two electric motors EMA, EMB. The example graph of Figure 5 illustrates engine, motor and output power best suited for the IB-EV mode during the example drive cycle.

[0026] The inventors have determined that the most optimum point of operation in the IB-EV mode (at the requested level of output torque) will be the point that minimizes battery power. To determine this point, an operating window within which the torque sources can operate is initially determined at step 406. This will be a function of motor torque limits at their respective speeds, clutch torque limits and battery power limits. Once the window is found, a motor operation control process such as e.g., the one disclosed in U.S. Application no. 61/513,112; filed July 29, 2011; (Chrysler Attorney docket no. 708612US1) and titled "Motor Operation Control System for an Electrically Variable Transmission," the disclosure incorporated herein by reference, will determine the necessary torques needed to fulfill the output torque request with minimum battery power usage. This required battery power along with various other auxiliary loads such as e.g., power consumption for the clutch actuation mechanism, will be used to determine the cost of operating the hybrid transaxle in the IB-EV mode. The cost will also reflect other things that affect drivability such as whether there is sufficient torque/power available in the system to start the engine.

[0027] Steps 408 and 412 calculate the costs for operating the system in the two under drive modes. Step 408 calculates the cost for operating the system in the UD-EV mode, shown as function $f_{EV}(P_{Disch}, P_{Electrical})$, and step 412 calculates the cost for operating the system in the UD-EO mode, shown as function $f_{EO}(P_{Disch}, P_{Engine}, P_{Electrical})$. P_{Engine} is the penalty for operating the engine.

[0028] As mentioned above, under drive is achieved by engaging the first clutch CB_1 while disengaging the second clutch C_2. Engaging the first clutch CB_1 while keeping the second clutch C_2 disengaged/open allows a higher gear ratio between the engine and the main planetary carrier. This significantly increases the mechanical path (i.e., the engine torque contribution to the output torque) of the hybrid transaxle. This mode is desirably used for accelerating the vehicle or when the vehicle is run under load. The example graph of Figure 6 illustrates output and engine speeds best suited for the under drive modes during the example drive cycle. The example graph of Figure 7 illustrates output, engine and main planetary torques best suited for the over drive modes during the example drive cycle.

[0029] Steps 408 and 412 will find the most optimum point of operation of the hybrid system for the two under drive modes for a given output power demand. The desired battery power $P_{batt_{des}}$ will be determined based on the driver requested output power P_{oreq} and the state of charge of the battery. The desired engine power P_e can be determined as follows:

(1) $P_e = P_{oreq} + P_{batt_{des}} + P_{Losses_{electrical}} + P_{Losses_{mechanical}}$

[0030] $P_{Losses_{electrical}}$ are the losses associated with running the electrical path (i.e., the electric motors). $P_{Losses_{mechanical}}$ are the losses associated with running the mechanical path (i.e., the internal combustion engine). $P_{Losses_{electrical}}$ and $P_{Losses_{mechanical}}$ are determined by an optimizer typically found in a hybrid system. The optimizer periodically calculates the most efficient points for operating the hybrid electrical and mechanical systems (at approximately every 100 milliseconds); $P_{Losses_{electrical}}$ and $P_{Losses_{mechanical}}$ are part of the optimizer's calculations.

[0031] As with step 406, an operating window within which the torque sources can operate will be determined at steps 408 and 412. These windows will be a function of motor torque limits at their respective speeds, clutch torque limits, engine torque limits and battery power limits. Once the windows of possible operation are found, the steps will determine what engine speed and torque will minimize the cost of operating the system at the above specified power level.

[0032] Steps 410 and 414 calculate the costs for operating the system in the two over drive modes. Step 410 calculates the cost for operating the system in the OD-EV mode, shown as function $f_{EV}(P_{Disch}, P_{Electrical})$, and step 414 calculates the cost for operating the system in the OD-EO mode, shown as function $f_{EO}(P_{Disch}, P_{Engine}, P_{Electrical})$. As set forth above, to implement over drive, the second clutch C_2 is engaged and the first clutch CB_1 is disengaged. Engaging clutch C_2 while keeping clutch CB_1 open enables a lower gear ratio between the engine and the main planetary carrier. This allows the hybrid transaxle to run at a lower input-to-output ratios, allowing the engine to stay in its optimum operating region for highway and low power demand operating conditions. Figure 6 also illustrates output and engine speeds best suited for the over drive modes during the example drive cycle. Figure 7 also illustrates output, engine and main planetary torques best suited for the under drive modes during the example drive cycle.

[0033] Steps 410 and 414 will find the most optimum point of operation of the hybrid system for the two over drive modes for a given output power demand. Similar to steps 408 and 412, the desired battery power $P_{batt_{des}}$ will be determined based on the driver requested output power P_{oreq} and the state of charge of the battery. Thus, the desired engine power P_e will be determined using equation (1) shown above.

[0034] As with steps 406, 408 and 412, an operating window within which the torque sources can operate will be determined at steps 410 and 414. These windows will be a function of motor torque limits at their respective speeds, clutch torque limits, engine torque limits and battery power limits. Once the windows of possible operation are found, the steps will determine what engine speed and torque will minimize the cost of operating the system at the above specified power level.

[0035] At step 416, the process selects the mode with the lowest cost of the five calculated costs from steps 406-414. At this point, pedal position, engine speed and the present mode and certain other drivability constraints are accounted for at step 418 before sending the appropriate mode to the control system (at step 420). The constraints could include shift busyness, constant changes in engine speeds down to optimization sensitivity, undesirable engine speed fluctuations, etc. At step 420 the final determination selecting the appropriate mode is made and sent to the control system.

[0036] At this point, the process 400 has placed the drive system in its most optimum operating condition for the current point in the drive cycle. The process efficiently switches between drive modes and gear ratios to optimize the system's and vehicle's driving performance. Smoother shifts between gear ratios will increase the driver's experience. The process 400 will also improve the vehicle's fuel economy by maximizing the use of the electric motors.

[0037] Figure 8 is a block diagram of a portion of a vehicle's powertrain 800 incorporating a supervisory hybrid electric vehicle controller 802 for executing the process 400 disclosed herein. The powertrain 800 also includes an input speed profiler 804, a constraints evaluator 806, a feedforward controller 808, feedback controller 810, the engine, first and second clutches CB_1, C_2, first and second electric motor controllers 812, 814 for respectively controlling the first and second electric motors EMA, EMB, and a hybrid transmission plant 820. The supervisory hybrid electric vehicle controller 802 executes process 400 and inputs pedal position and the various other vehicle operating conditions and parameters discussed above with reference to process 400. Outputs from the supervisory hybrid electric vehicle controller 802 are used to control the engine, clutches CB_1, C_2 and the motors EMA, EMB (via the input speed profiler 804, constraints evaluator 806, feedforward controller 808, motor controllers 812, 814, and the feedback controller 810) in accordance with the process 400 described herein. The other operations of the powertrain 800, including the input speed profiler 804, constraints evaluator 806, feedforward controller 808, the feedback controller 810, as well as the various parameters used by these components, are discussed in more detail in U.S. Application no. 61/513,061 (Chrysler Attorney docket no. 708620US1).

CLAIMS

What is claimed is:

1. A method of selecting a mode of operation of a vehicle having an electrically variable transmission, said method comprising using a processor to perform the steps of:

determining a battery discharge penalty;

determining a cost associated with operating an electrical portion of the transmission;

determining a cost associated with operating a mechanical portion of the transmission;

calculating respective costs for operating the vehicle in a plurality of operating modes based on the battery discharge penalty and the costs associated with operating the electrical and mechanical portions of the transmission; and

selecting an operating mode having the lowest calculated cost.

2. The method of claim 1, further comprising:

determining an output speed of the vehicle;

determining a desired output torque of the transmission; and

determining a state of charge of the battery.

3. The method of claim 2, wherein the battery discharge penalty is determined based on the output speed, output torque and state of charge of the battery.

4. The method of claim 2, further comprising inputting a speed of the vehicle and a pedal position of the vehicle's throttle, wherein the output speed and desired output torque are determined based on the input speed and pedal position.

5. The method of claim 1, wherein the electrically variable transmission comprises at least one braking clutch and the modes of operation comprise an input brake electric vehicle mode, a plurality of over drive modes and a plurality of under drive modes.

6. The method of claim 5, wherein the plurality of over drive modes comprises an over drive electric vehicle mode and an over drive engine on mode.

7. The method of claim 5, wherein the plurality of under drive modes comprises an under drive electric vehicle mode and an under drive engine on mode.

8. The method of claim 1, further comprising commanding a control system of the vehicle to change the operating mode to the selected operating mode having the lowest calculated cost.

9. The method of claim 8, further comprising determining a drivability impact of a mode change before commanding the control system to change the operating mode.

10. A controller for selecting a mode of operation of a vehicle having an electrically variable transmission, said controller comprising:

a processor programmed to:

determine a battery discharge penalty;

determine a cost associated with operating an electrical portion of the transmission;

determine a cost associated with operating a mechanical portion of the transmission;

calculate respective costs for operating the vehicle in a plurality of operating modes based on the battery discharge penalty and the costs associated with operating the electrical and mechanical portions of the transmission; and

select an operating mode having the lowest calculated cost.

11. The controller of claim 10, wherein the processor is further programmed to:

determine an output speed of the vehicle;

determine a desired output torque of the transmission; and

determine a state of charge of the battery.

12. The controller of claim 11, wherein the battery discharge penalty is determined based on the output speed, output torque and state of charge of the battery.

13. The controller of claim 11, wherein the processor is further programmed to input a speed of the vehicle and a pedal position of the vehicle's throttle, and wherein the output speed and desired output torque are determined based on the input speed and pedal position.

14. The controller of claim 10, wherein the electrically variable transmission comprises at least one braking clutch and the modes of operation comprise an input brake electric vehicle mode, a plurality of over drive modes and a plurality of under drive modes.

15. The controller of claim 14, wherein the plurality of over drive modes comprises an over drive electric vehicle mode and an over drive engine on mode.

16. The controller of claim 15, wherein the plurality of under drive modes comprises an under drive electric vehicle mode and an under drive engine on mode.

17. The controller of claim 10, wherein the processor is further programmed to command a control system of the vehicle to change the operating mode to the selected operating mode having the lowest calculated cost.

18. The controller of claim 15, wherein the processor is further programmed to determine a drivability impact of a mode change before commanding the control system to change the operating mode.

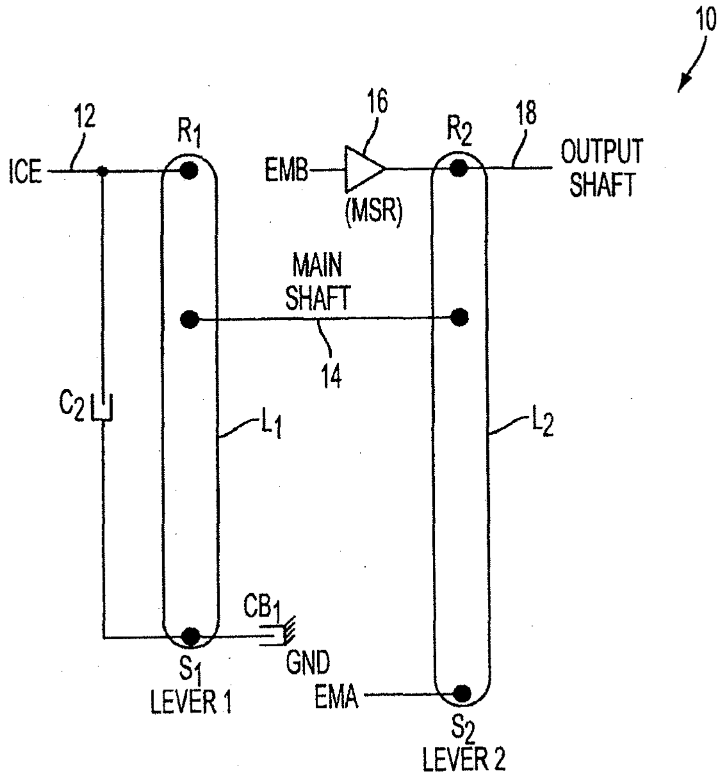
10
12
ICE
R_1
16
EMB
(MSR)
R_2
18
OUTPUT SHAFT
MAIN SHAFT
14
C_2
L_1
L_2
CB_1
GND
S_1
LEVER 1
EMA
S_2
LEVER 2

FIG. 1

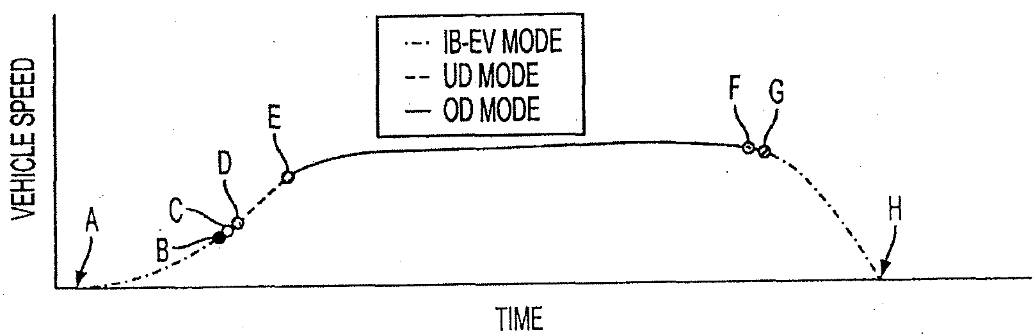
IB-EV MODE
UD MODE
OD MODE
VEHICLE SPEED
TIME
A
B
C
D
E
F
G
H

FIG. 2

POINT (S)	DESCRIPTION
A	VEHICLE STARTS IN IB-EV MODE. MOTORS A AND B PROPEL THE VEHICLE
A TO B	VEHICLE OPERATES IN IB-EV MODE. MOTORS A AND B PROPEL THE VEHICLE
B	IB-EV TO OD-EV SHIFT. MOTOR B PROPELS THE VEHICLE
B TO C	OD-EV MODE. MOTOR B PROPELS THE VEHICLE. MOTOR A ACCELERATES THE ENGINE
C	ENGINE STARTS. OD-EV TO OD-EO TRANSITION
C TO D	OD-EO MODE. ENGINE AND MOTORS PROPEL THE VEHICLE
D	OD-EO TO UD-EO SHIFT
D TO E	UD-EO MODE. ENGINE AND MOTORS PROPEL THE VEHICLE. HIGHER RATIO FROM ENGINE TO OUTPUT
E	UD-EO TO OD-EO SHIFT
E TO F	OD-EO MODE. ENGINE AND MOTORS PROPEL THE VEHICLE. LOWER RATIO FROM ENGINE TO OUTPUT
F	ENGINE SHUT-OFF. OD-EO TO OD-EV TRANSITION. MOTOR B PROPELS THE VEHICLE OR PROVIDES REGENERATIVE BRAKING AS NEEDED
F TO G	OD-EV MODE. MOTOR B PROPELS THE VEHICLE OR PROVIDES REGENERATIVE BRAKING AS NEEDED. MOTOR A SPINS ENGINE DOWN TO ZERO SPEED
G	OD-EV TO IB-EV SHIFT. BOTH MOTORS A AND B PROVIDE REGENERATIVE BRAKING (OR PROPULSION) AS NEEDED
G TO H	IB-EV MODE. BOTH MOTORS A AND B PROVIDE REGENERATIVE BRAKING (OR PROPULSION) AS NEEDED
H	VEHICLE STOPS IN IB-EV MODE

FIG. 3

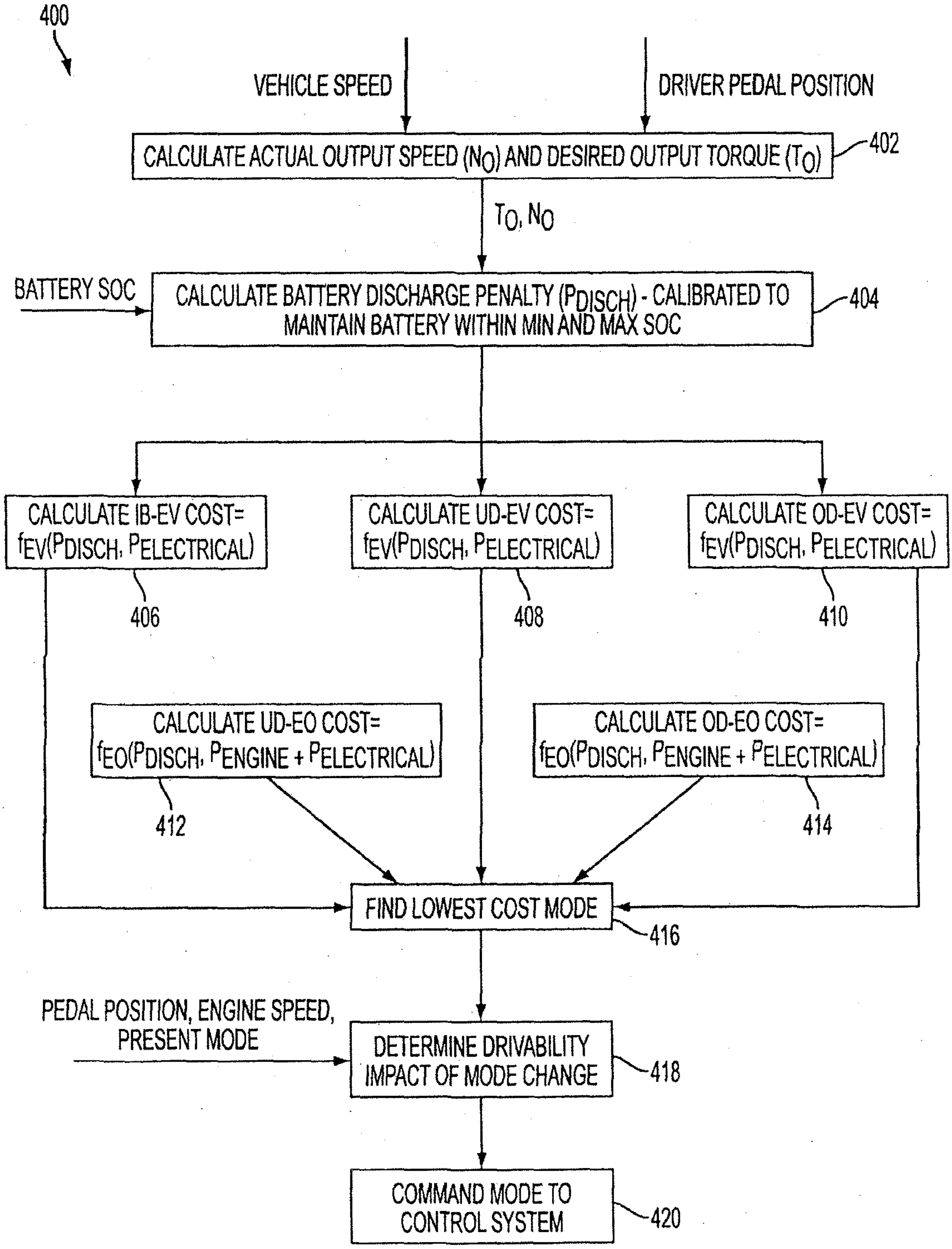
400
VEHICLE SPEED
DRIVER PEDAL POSITION
CALCULATE ACTUAL OUTPUT SPEED (N_O) AND DESIRED OUTPUT TORQUE (T_O)
402
T_O, N_O
BATTERY SOC
CALCULATE BATTERY DISCHARGE PENALTY (P_{DISCH}) - CALIBRATED TO MAINTAIN BATTERY WITHIN MIN AND MAX SOC
404
CALCULATE IB-EV COST= $f_{EV}(P_{DISCH}, P_{ELECTRICAL})$
406
CALCULATE UD-EV COST= $f_{EV}(P_{DISCH}, P_{ELECTRICAL})$
408
CALCULATE OD-EV COST= $f_{EV}(P_{DISCH}, P_{ELECTRICAL})$
410
CALCULATE UD-EO COST= $f_{EO}(P_{DISCH}, P_{ENGINE} + P_{ELECTRICAL})$
412
CALCULATE OD-EO COST= $f_{EO}(P_{DISCH}, P_{ENGINE} + P_{ELECTRICAL})$
414
FIND LOWEST COST MODE
416
PEDAL POSITION, ENGINE SPEED, PRESENT MODE
DETERMINE DRIVABILITY IMPACT OF MODE CHANGE
418
COMMAND MODE TO CONTROL SYSTEM
420

FIG. 4

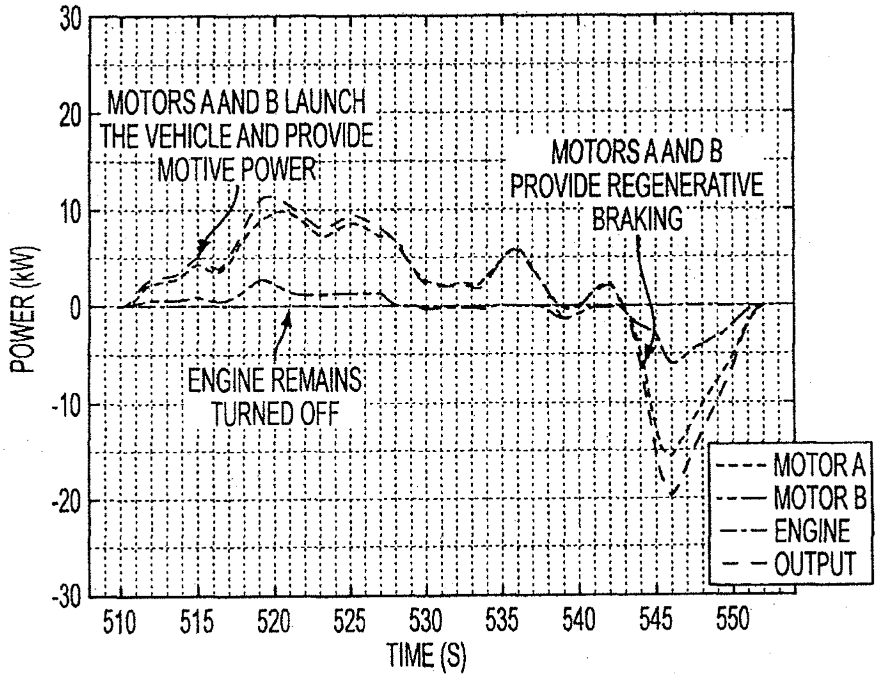

FIG. 5

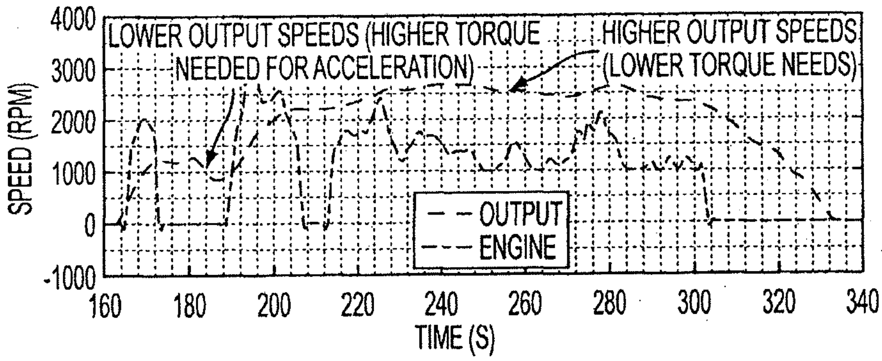

FIG. 6

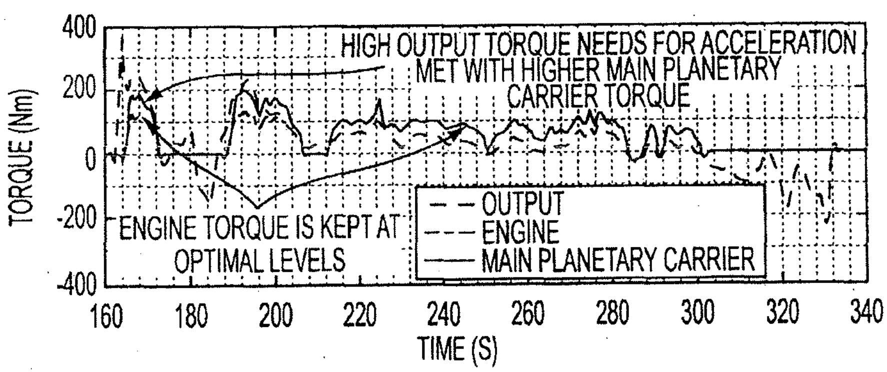

FIG. 7

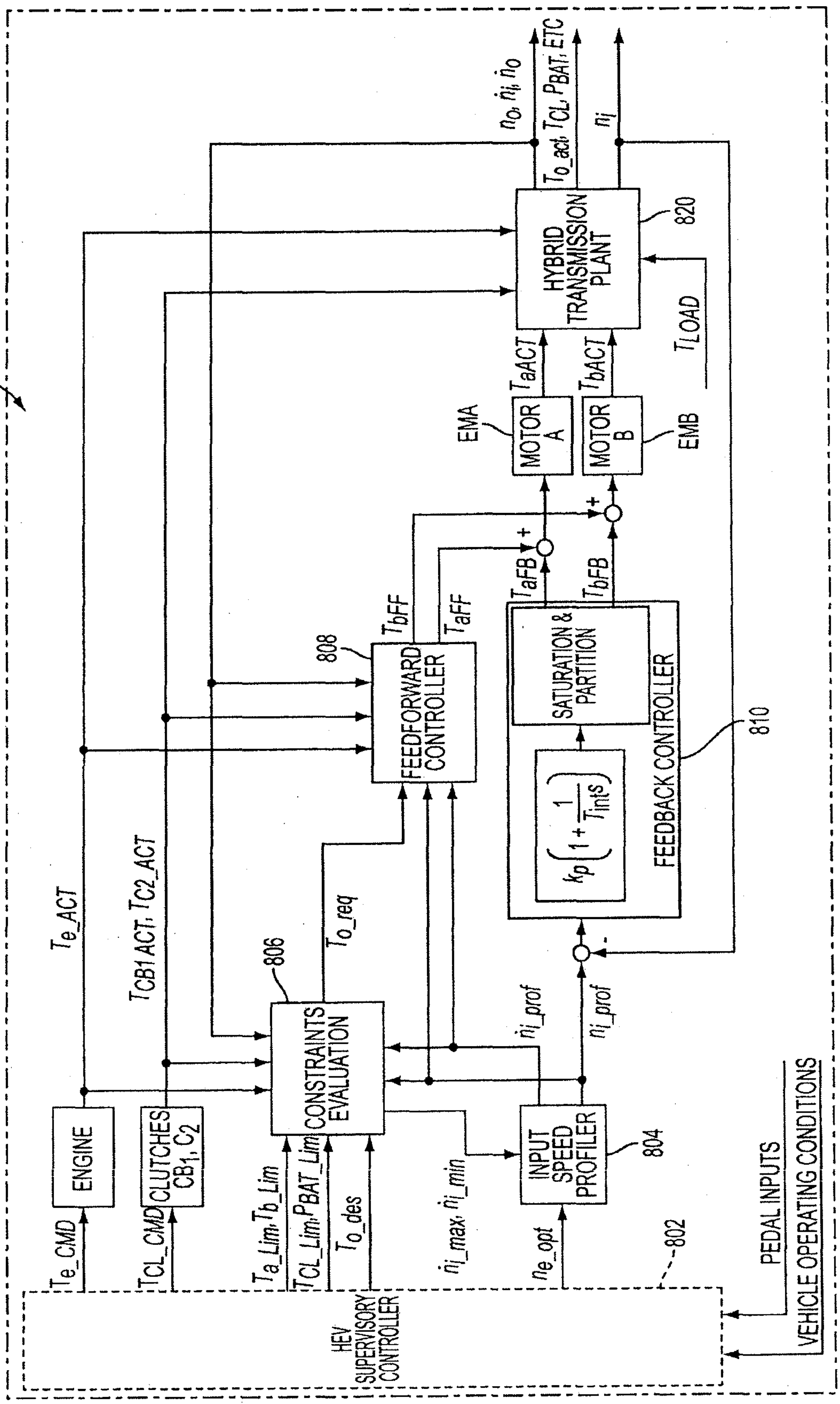
800
HEV SUPERVISORY CONTROLLER
802
PEDAL INPUTS
VEHICLE OPERATING CONDITIONS
Te_CMD
TCL_CMD
ENGINE
CLUTCHES CB1, C2
Te_ACT
TCB1 ACT, TC2_ACT
Ta_Lim, Tb_Lim
TCL_Lim, PBAT_Lim
To_des
ni_max, ni_min
ne_opt
CONSTRAINTS EVALUATION
806
INPUT SPEED PROFILER
804
To_req
ni_prof
FEEDFORWARD CONTROLLER
808
TbFF
TaFF
SATURATION & PARTITION
FEEDBACK CONTROLLER
810
TaFB
TbFB
MOTOR A
MOTOR B
EMA
EMB
TaACT
TbACT
HYBRID TRANSMISSION PLANT
820
TLOAD
To_act, TCL, PBAT, ETC
no, ni, no
ni

FIG. 8

PATENT COOPERATION TREATY

PCT

DECLARATION OF NON-ESTABLISHMENT OF INTERNATIONAL SEARCH REPORT

(PCT Article 17(2)(a), Rules 13*ter*.1(c) and Rule 39)

Applicant's or agent's file reference C35020112P112PC	IMPORTANT DECLARATION	Date of mailing *(day/month/year)* 17 December 2012 (17-12-2012)
International application No. PCT/US2012/047958	International filing date *(day/month/year)* 24 July 2012 (24-07-2012)	(Earliest) Priority date *(day/month/year)* 29 July 2011 (29-07-2011)
International Patent Classification (IPC) or both national classification and IPC B60W10/06		
Applicant CHRYSLER LLC		

This International Searching Authority hereby declares, according to Article 17(2)(a), that **no international search report will be established** on the international application for the reasons indicated below

1. ☐ The subject matter of the international application relates to:
   - a. ☐ scientific theories
   - b. ☐ mathematical theories
   - c. ☐ plant varieties
   - d. ☐ animal varieties
   - e. ☐ essentially biological processes for the production of plants and animals, other than microbiological processes and the products of such processes
   - f. ☐ schemes, rules or methods of doing business
   - g. ☐ schemes, rules or methods of performing purely mental acts
   - h. ☐ schemes, rules or methods of playing games
   - i. ☐ methods for treatment of the human body by surgery or therapy
   - j. ☐ methods for treatment of the animal body by surgery or therapy
   - k. ☐ diagnostic methods practised on the human or animal body
   - l. ☐ mere presentations of information
   - m. ☐ computer programs for which this International Searching Authority is not equipped to search prior art
2. ☐ The failure of the following parts of the international application to comply with prescribed requirements prevents a meaningful search from being carried out:
   ☐ the description ☐ the claims ☐ the drawings
3. ☐ A meaningful search could not be carried out without the sequence listing; the applicant did not, within the prescribed time limit:
   - ☐ furnish a sequence listing on paper complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.
   - ☐ furnish a sequence listing in electronic form complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.
   - ☐ pay the required late furnishing fee for the furnishing of a sequence listing in response to an invitation under Rule 13*ter*.1(a) or (b).
4. Further comments:

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040 Fax: (+31-70) 340-3016	DORPEMA, Anne Tel: +49 (0)89 2399-8211

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The application lacks clarity to such an extent that no meaningful search is possible (Article 6 PCT).
1. Claim 1 refers to various parameters, in particular a battery discharge penalty. Claim 1 further refers to costs associated with operating an electrical or mechanical portion of the transmission. The transmission can be placed in several operating modes. To take a decision between these modes, the respective operating costs are calculated, based on dischargepenalty and the costs associated with operating the electrical and mechanical portions of the transmission. The mode with the lowest calculated costs is selected.
2. There are several issues which require clarification.
2.1 The "battery discharge penalty" is not defined. Paragraph 24 simply states that this penalty is calculated and calibrated, to maintain the battery within a minimum and maximum state of charge range. There is no definition at all as to what a "battery discharge penalty" might be. Further, it is not clear what a "a minimum and maximum state of chargerange " might be. It does not appear to be intended to keep the battery between a minimum and maximum state of charge (if that were the case, the "range" would not be there).
2.2 The "most optimum point of operation" minimizes battery power (paragraph 26). First, there is no "most optimum", second, "battery power" is also not defined.
Assuming battery input/output power is meant, the "most optimum point" would be not to use the battery at all. The "IB-EV mode", however, does not appear to use the engine and accordingly has to rely on the battery, leading to the conclusion that either this mode is not optimal or that there is some misunderstanding.
2.3 The electrical costs are the penalty/cost for operating the electric motors. It is not clear whether this is the electric power delivered to the electric motors. Assuming this is the case, this is not a penalty.
2.4 The mechanical cost is not understood. The description continuously refers to PEngine (see e.g. paragraph 27). The engine, however, is not a mechanical portion of the transmission. Input shaft (12) of the transmission is connected to an output shaft of the engine (ICE), see paragraph 17 and Figure 1. Again in paragraph 27, PEngine is the penalty for operating the engine. It is not clear what the "penalty" means, as soon as the engine is running, it will consume fuel. This is not a penalty.
2.5 In addition to PEngine and PElectrical, there are power losses, see paragraph 29 and equation 1. It is not clear how these losses are related to the penalties.
3. As best understood, the application considers constraints (torque of the engine/motors, battery charge state) when deciding how to operate the vehicle in order to meet driver demand. The aim is to arrive at a mode of operation which has the lowest calculated cost, presumable the lowest energy consumption.
This approach is known, see US 2011/0130901 A (D1), abstract and claim 1.
D1, Figure 2, discloses a vehicle having one internal combustion engine (ICE) and two electric motors (EM1, EM2). D1, claim 1, considers driver demand, torque constraints and operating efficiency, battery charge state is discussed in paragraph 57.
The transmission underlying the application is known, see e.g. US 2009/0115349 A (D2).
4. Claim 10 is drafted in line with claim 1. The same objections apply.
The dependent claim suffer from the same defects as the independent

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claims, due to their dependency.
5. To summarize, claim 1 relies on features which lack clarity (Article 6 PCT). The whole application lacks clarity, due to apparent failure to describe the calculations and by lack of distinction between the transmission and the engine (Article 6 PCT). There is probably also an issue with enabling disclosure (Article 5 PCT).
On top, it seems that the approach of at least claims 1 and 10 is known in the prior art.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.2), should the problems which led to the Article 17(2) declaration be overcome.