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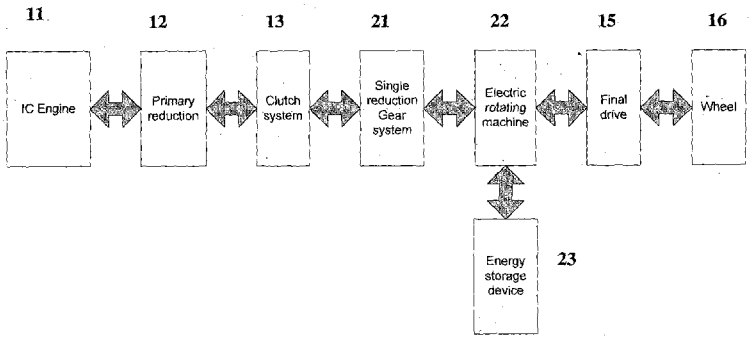
(54) Title: INTEGRATED UNIT FOR MOTOR INTEGRATED HYBRID TRANSMISSION CONTROL AND ENGINE CONTROL



(57) Abstract: The present invention proposes a system of electrically controlled integrated unit consisting of a single gear reduction system 21 with an electric rotating machine with double rotor configuration 22 instead of the multiple gear system 14 of the existing system. This control system includes an IC engine 11 control, clutch system 13 control and electric rotating machine with double rotor configuration 22 control systems. The electric rotating machine with double rotor configuration 22 works in all four quadrant modes not limiting the functionality of the proposed system. Therefore, the effect of the absence of the multiple gear system 14 is compensated by the power output of the electric motor and the drivability of the proposed system becomes equivalent to that of a geared vehicle.

WO 2013/168183 A1

INTEGRATED UNIT FOR MOTOR INTEGRATED HYBRID TRANSMISSION CONTROL AND ENGINE CONTROL

BACKGROUND

FIELD OF THE INVENTION

An integrated unit for motor integrated hybrid transmission control and engine control.

DISCUSSION OF PRIOR ART

US6837816 titled ***"Motor integrated parallel hybrid transmission"*** describes a motor integrated transmission mechanism for use in parallel hybrid electric vehicles. This transmission provides five modes of operation further classified into sixteen sub types of the operation .i.e. one electric motor mode, four engine modes, four engine/charge modes, three power modes and four regenerative braking modes. The combination of torque transfer devices and compound planetary gear train of the invention provides the improved hybrid vehicle transmission while maintaining a simple, reliable transmission construction operable through engine only, motor only and combined engine and motor torque transmission to the transmission output shaft. This hybrid transmission can be used in front-wheel drive and rear-wheel drive vehicles.

US6890283 titled ***"Control apparatus for controlling transmission of hybrid vehicle"*** describes a control apparatus for controlling the transmission of a hybrid vehicle which includes an engine, a motor for transmitting power to the wheels independently of the engine and a transmission arranged between the engine and the wheels. This has minimum of one power connection/disconnection means arranged in accordance with the driving conditions.

US7931555 titled ***"Hybrid drive device"*** describes an hybrid drive apparatus, which includes an engine, an input shaft that is connected to engine and an output shaft that is connected the wheels, rotary electric machine, first planetary gear apparatus, second planetary gear apparatus. The first planetary gear apparatus reduces the value

of rotational speed of rotary electric machine and transfers a first resulting rotational speed to the second planetary gear apparatus, which combines the first resulting rotational speed and the rotation of the input shaft and reduces value of rotational speed of input shaft and finally transfers the second resulting rotational speed to the output shaft.

US7493980 titled *"Mode transition control system for hybrid vehicle"* describes a mode transition control apparatus which includes a hybrid drive system having a first clutch placed between engine and a motor generator, and a second clutch placed between the motor generator and wheel, an engine breaking request judging section to judge whether a request of an engine braking is present during a motor regenerative braking performed by the motor generator, and a mode transition control section to perform a mode transition control of the hybrid drive system in accordance with a transition request. The mode transition control apparatus is configured to decrease a torque capacity of the second clutch, which is involved in response to the judgment that the request of the engine braking is present, and to bring the first clutch from a disengaged state to the engaged state to shift to the engine braking.

In normal driving mode, power flows from IC engine to wheel through the path mentioned in Figure 1. In case of vehicle braking or deceleration condition, the power flows in the reverse path. The engine can be operated at a desired region by selecting a suitable gear ratio of multiple gear system. The desired region may be decided by a human driver for a manual transmission depending on drivability and fuel efficiency. In case for a CVT /automated transmission, the desired gear ratio is selected automatically on certain vehicle parameters and driver selectable modes.

There are certain disadvantages of the system

- System efficiency may be very less for certain operating region

- There may be torque dead zone during transition of gear ratio for a non CVT configuration
- The transient response may be slow for certain operating region
- There is no energy recovery system

SUMMARY OF THE INVENTION

The present invention relates to an electronic controller to control the full system, which includes IC engine control, clutch system control and electric rotating machine with double rotor configuration control. This electronic control system contains set of sensors and calculates the control parameters like engine control parameters, ignition timing, dwell timing, fuel injection time, fuel pump duty cycle, idle speed actuator, throttle opening, clutch engagement/disengagement percentage, motor/generator power requirement and power dumping requirement to the energy storage device. The proposed system consists of a single gear reduction system with an electric rotating machine instead of the multiple gear system. The uniqueness of the proposed system is that the drivability is equivalent to a geared vehicle. The effect of absence of multiple gear system is compensated by the power output of the electric motor. The single reduction gear system reduces the engine speed to operating region of electric rotating machine with double rotor configuration speed. The electric rotating machine with double rotor configuration works in four quadrant modes. The functionality of the proposed system is not limited by the type of the rotating machine integrated in the system. The energy storage device supplies and recovers energy from the electric rotating machine with double rotor configuration depending on the vehicle operating region. Part of engine braking is realized by operating the electric rotating machine in 4^{th} /3^{rd} quadrant mode during vehicle deceleration for forward/reverse operation respectively. The advantages of the system are:

- Total system efficiency can be improved by operating both engine and motor and best possible operating region
- Transient response is better as there is no torque interruption
- Energy can be recovered during certain operating region

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates the drive power flow in a conventional vehicle.

Figure 2 illustrates the proposed system according to the invention.

Figure 3 illustrates the input and output diagram of the proposed integrated unit.

Figure 4 illustrates the top level system diagram for the full system.

DETAILED DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates the drive power flow in a conventional vehicle. The power flow may be bidirectional in certain driving conditions. The block **11** represents the power source for most of operating condition of the vehicle. The 2nd block is the primary reduction gear **12** to reduce angular speed. The 3rd block is the clutch system **13,** which may be any of the following types

- Dry clutch system
- Wet clutch system
- Centrifugal clutch system
- Electromagnetic clutch system
- Torque converter

The 4th block represents the multiple gear system **14**. This system may be any of the following types

- Multiple gear system with respective fixed ratio
- Continuous variable transmission (CVT)

The 5th block is a final drive system **15,** which may be of following types

- Chain drive system
- Propeller shaft system

The last block is a wheel **16,** which interacts with the road.

The gear and clutch actuation can be realized manually or automatically depending on the transmission system configuration.

In normal driving mode, power flows from IC engine **11** to wheel **16** through the path as mentioned in **Figure 1**. In case of vehicle braking or deceleration condition, the power flows in the reverse path. The engine can be operated at a desired region by selecting a suitable gear ratio of multiple gear system **14**. The desired region may be decided by a human driver for a manual transmission depending on drivability and fuel efficiency. In case for a CVT /automated transmission, the desired gear ratio is selected automatically on certain vehicle parameters and driver selectable modes.

Figure 2 illustrates the proposed system. The proposed system consists of a single gear reduction system **21** with an electric rotating machine with double rotor configuration **22** instead of a multiple gear system **14** of the existing system. The single reduction gear system **21** reduces the engine speed to operating region of the electric rotating machine with double rotor configuration **22** speeds. The electric rotating machine with double rotor configuration **22** works in four quadrant modes. The functionality of the proposed system is not limited by the type of the rotating machine integrated in the system. An energy storage device **23** supplies and recovers energy from the electric rotating machine with double rotor configuration **22** depending on the vehicle operating region. The system has the following advantages

- Total system efficiency can be improved by operating both engine and motor and best possible operating region
- Transient response is better as there is no torque interruption
- Energy can be recovered during certain operating region

Figure 3 illustrates the input and output diagram of the proposed integrated unit.

The following inputs are used for engine control function. Depending on the engine configuration, combinations of the certain inputs are used.

- Engine speed and position sensor signal **31**
- Intake air temperature sensor signal **34**
- Engine cylinder head temperature sensor signal **32**
- Transmission oil temperature sensor signal **33**
- Throttle position sensor signal **36**
- Intake air flow sensor signal **35**
- Manifold air pressure sensor signal **39**
- Knock sensor signal **43**
- Lambda sensor signal **42**
- Fuel selection signal **54**
- Vehicle speed sensor signal **40**
- Automatic economy drive mode select signal **56**
- Automatic sporty drive mode select signal **56**
- Manual drive mode select signal **57**
- CAM shaft signal **45**

The following inputs are used for transmission drive motor control function. Depending on the refinement of control software requirement, combinations of the certain inputs are used

- Engine speed sensor signal **31**
- Vehicle speed sensor signal **40**
- Transmission output shaft speed sensor signal **44**
- Clutch position sensor signal **38**
- Gear down select switch signal **53**
- Gear up select switch signal **52**
- Brake position signal **47**
- Automatic economy drive mode select signal **56**
- Automatic sporty drive mode select signal **56**
- Manual drive mode select signal **57**
- Battery/Ultra capacitor voltage sensor signal **50**
- Battery/Ultra capacitor current sensor signal **51**
- Transmission drive motor current sensor signal **48**

The following inputs are used for safety critical functions for the integrated controller

- Seat occupancy sensor signal **46**
- Vehicle tilt sensor signal **41**
- Side stand switch signal **55**

The following inputs are used for start stop functionality of the integrated controller

- Throttle position sensor signal **36**
- Brake position sensor signal **47**

- Seat occupancy sensor signal **46**
- Vehicle speed sensor signal **40**

The left hand side of **Figure 3** represents the input signals for the control system including:

- Clutch actuator current sensor **49**: It senses the clutch actuator current for load control on clutch.
- Gear position sensor **37**: This sensor gives information on whether the system is on geared condition or neutral condition for controlling clutch drag.
- Engine start-stop signal **58**: This is a driver command interface for selecting start or stop of the vehicle
- Fuel selection mode **55**: This information will ensure engine control option for alternate fueled vehicle

The following outputs are used for engine control functionality depending upon engine configuration

- Fuel injector output **68**
- Spark timing output **67**
- Fuel pump output **66**
- Engine cooling fan output **63**
- Canister purge valve output **64**
- Idle speed control valve output **62**
- Secondary air input control valve **70**
- Automatic chock control valve **69**

The following outputs are used for drive motor control functionality

- Drive motor output **59**
- Clutch shift actuator output **60**
- Electronic throttle control actuator output **61**
- Secondary air path control actuator output **71**
- Energy flow control for the alternate power source **85**

The following output is used for start stop functionality

- Starter relay coil output **65**

Figure 4 illustrates the top level system diagram for the full system, which includes the following subsystems:

- Control system **81**: The control system **81** works as a supervisory method to control all the subsystems. It takes the feedback signals from all the sensors to read the system parameters. The system parameters are read from the plant **86**. The subsystem controls are not mutually exclusive. So, the overall supervisory control needs to consider the coupling before triggering the subsystem control. The subsystems **82**, **83**, **84** and **85** works as a multivariable input output system.
- Internal combustion engine control **82**: The subsystems for control are functionally divided as shown in **Figure 4**. The top most diagram shows the control block for IC engine **11** control. It controls the IC engine torque output and emission output as instructed by **81**.
- Control of electric machine coupled to transmission **83**: This subsystem controls the power output of the electric machine depending on the vehicle operating condition

- Clutch system activation control **84**: This subsystem controls clutch system operation during all the vehicle operating modes
- Energy transfer control **85**: As the proposed system comprised of an auxiliary power source, the energy transfer control becomes very crucial, which should not affect the drivability of the vehicle.
- Plant parameters **86**: Plant is the engine with full transmission system. The parameters of the system are very important for taking the control decision. The plant parameters can be read by the control system through a suitable interface as shown in the left hand side of **Figure 3**.

The engine control functionality performs the following functions with the integrated control unit

1. Static and dynamic engine torque output according to the driver command
2. Change of engine transient response according to manual driver mode selection
3. Automatic change of engine transient response with the driver usage style when automatic mode is selected
4. Idle speed control for various engine load condition
5. Engine torque damping for certain sharp transient operating condition
6. Knock control
7. Closed loop emission control
8. Engine start/stop functionality.

The transmission drive motor control functionality performs the following functions with the integrated control unit

1. Clutch launch control
2. Transmission motor drive power output control **83** according to the gear Up/Down command **52, 53** in manual mode drive

3. Transmission motor drive power output control **83** in either economy mode/sporty mode according to the driver mode selection
4. Safety interlock function for unsafe transmission motor drive power output control **83** during vehicle turning
5. Safety interlock function for unsafe transmission motor drive power output control **83** when driver is not occupied the seat.
6. Safety interlock function for unsafe transmission motor drive power output control **83** when driver is not removed the side stand of the vehicle.

There are several overlaps between the above mentioned functionality of engine control and AMT control. The overlaps are mentioned as below

- 1^{st} function of transmission motor drive power output control overlaps with 1^{st},2^{nd} ,3^{rd} ,4^{th} ,6^{th} and 7^{th} function of engine control
- 2^{nd} function of transmission motor drive power output control overlaps with 1^{st},2^{nd} ,4^{th} ,5^{th} ,6^{th} and 7^{th} function of engine control
- 3^{rd} function of transmission motor drive power output control overlaps with 1^{st},3^{rd} ,4^{th} ,5^{th} ,6^{th} and 7^{th} function of engine control

In this integrated unit, overlap of the functionalities is realized using less system resources then the configuration having two independent ECUs.

CLAIMS

1. An electrically controlled system, integrated into the vehicle comprising of:
   an IC engine **11;**
   a primary reduction gear **12;**
   a clutch system **13;**
   a single gear reduction system **21;**
   an electric rotating machine with double rotor configuration **22;**
   an energy storage device **23;**
   a final drive system **15;**
   a wheel **16;** and
   a control system **81** for accepting input from a plurality of sensors, comparing the sensed value with a predetermined decision matrix stored in the memory of the control system 81and generate out signals thereby determining the drivability, fuel consumption and emission of the vehicle.

2. The electrically controlled system, integrated into the vehicle as claimed in claim 1, wherein the control system 81 takes an engine parameters, an electrical machine parameters, a clutch parameters and a vehicle parameters as input.

3. The electrically controlled system, integrated into the vehicle as claimed in claim 1, wherein the said control system 81 controls the IC engine 11, an electric machine coupled to the transmission, a clutch activation system and an energy transfer as output.

4. The electrically controlled system, integrated into the vehicle as claimed in claim 1, wherein the electric rotating machine with double rotor configuration 22 works in four quadrant modes and the part of engine braking is realized by

operating the electric rotating machine with double rotor configuration 22 in 4^{th} /3^{rd} quadrant mode during vehicle deceleration for forward/reverse operation respectively.

5. The electrically controlled system, integrated into the vehicle as claimed in claim 1, wherein the said electrically controlled system consists of single gear reduction system.

6. The electrically controlled unit integrated into the vehicle as claimed in claim 1, wherein an engine function control has

a. One or more inputs including:

i. A engine speed and position sensor signal **31;**
ii. A intake air temperature sensor signal **34;**
iii. A engine cylinder head temperature sensor signal **32;**
iv. A transmission oil temperature sensor signal **33;**
v. A throttle position sensor signal **36;**
vi. A intake air flow sensor signal **35;**
vii. A manifold air pressure sensor signal **39;**
viii. A knock sensor signal **43;**
ix. A lambda sensor signal **42;**
x. A fuel selection signal **54;**
xi. A vehicle speed sensor signal **40;**
xii. An automatic economy drive mode select signal **56;**
xiii. An automatic sporty drive mode select signal **56;**
xiv. A manual drive mode select signal **57;** and
xv. A CAM shaft signal **45.**

b. One or more outputs including:

i. A fuel injector output **68;**

ii. A spark timing output **67;**
iii. A fuel pump output **66;**
iv. A engine cooling fan output **63;**
v. A canister purge valve output **64;**
vi. A idle speed control valve output **62;**
vii. A secondary air input control valve **70;** and
viii. An automatic chock control valve **69.**

7. The electrically controlled unit integrated into the vehicle as claimed in claim 1 wherein an engine function control with an integrated controller has one or more functions including:
   a. Static and dynamic engine torque output according to a driver command;
   b. Change of engine transient response according to manual driver mode selection;
   c. Automatic change of engine transient response with the driver usage style when automatic mode is selected;
   d. Idle speed control for one or more engine load condition;
   e. Engine torque damping for sharp transient operating condition;
   f. Knock control;
   g. Closed loop emission control;
   h. Engine start and stop functionality.

8. The electrically controlled unit integrated into the vehicle as claimed in claim 1wherein the said control system **81** is provided with
   a. Inputs for one or more safety critical functions including:
      i. A seat occupancy sensor signal **46;**
      ii. A vehicle tilt sensor signal **41;** and

iii. A side stand switch signal **55**.

b. Inputs for one or more start stop functionality including:

i. The throttle position sensor signal **36**;

ii. The brake position sensor signal **47;**

iii. The seat occupancy sensor signal **46;** and

iv. The vehicle speed sensor signal **40.**

9. The electrically controlled unit integrated into the vehicle as claimed in claim 1, wherein a transmission drive motor control function has

(a) one or more inputs including:

i. The engine speed sensor signal **31;**

ii. The vehicle speed sensor signal **40;**

iii. An transmission output shaft speed sensor signal **44;**

iv. A clutch position sensor signal **38;**

v. A gear down select switch signal **53;**

vi. A gear up select switch signal **52;**

vii. The brake position signal **47;**

viii. An automatic economy drive mode select signal **56;**

ix. An automatic sporty drive mode select signal **56;**

x. The manual drive mode select signal **57;**

xi. An ultra capacitor voltage sensor signal **50;**

xii. An ultra capacitor current sensor signal **51;** and

xiii. A transmission drive motor current sensor signal **48;**

(b) one or more outputs including:

i. An drive motor output **59;**

ii. An clutch shift actuator output **60;**

iii. An electronic throttle control actuator output **61;**

iv. A secondary air path control actuator output **71;** and

v. An energy flow control for an alternate power source **85.**

10. The electrically controlled unit integrated into the vehicle as claimed in claim 1wherein transmission drive motor control function with the integrated control unit has one or more functions including:

a. Clutch launch control;

b. Transmission motor drive power output control **83** according to the gear-Up-Down command **52, 53** in manual mode drive;

c. Transmission motor drive power output control **83** in economy mode/sporty mode according to the driver mode selection;

d. Transmission motor drive power output control **83** in sporty mode according to the driver mode selection;

e. Safety interlock function for unsafe transmission motor drive power output control **83** during vehicle turning;

f. Safety interlock function for unsafe transmission motor drive power output control **83** when driver is not occupied the seat; and

g. Safety interlock function for unsafe transmission motor drive power output control **83** when driver is not removed the side stand of the vehicle.

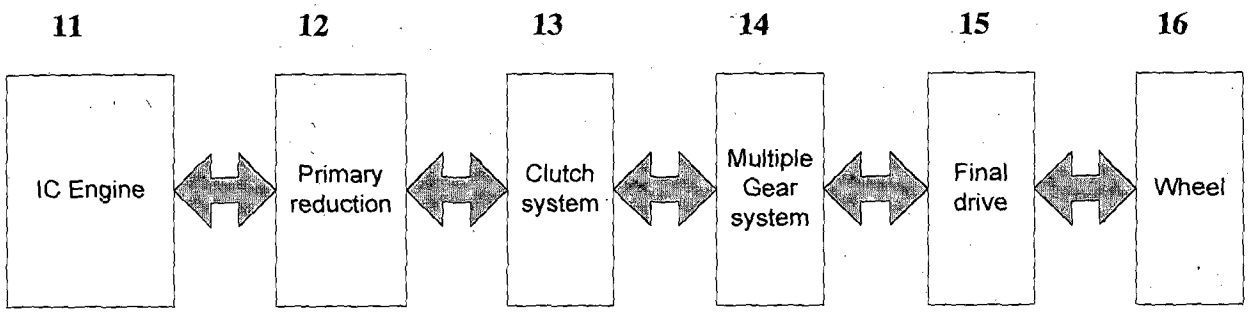


Figure 1

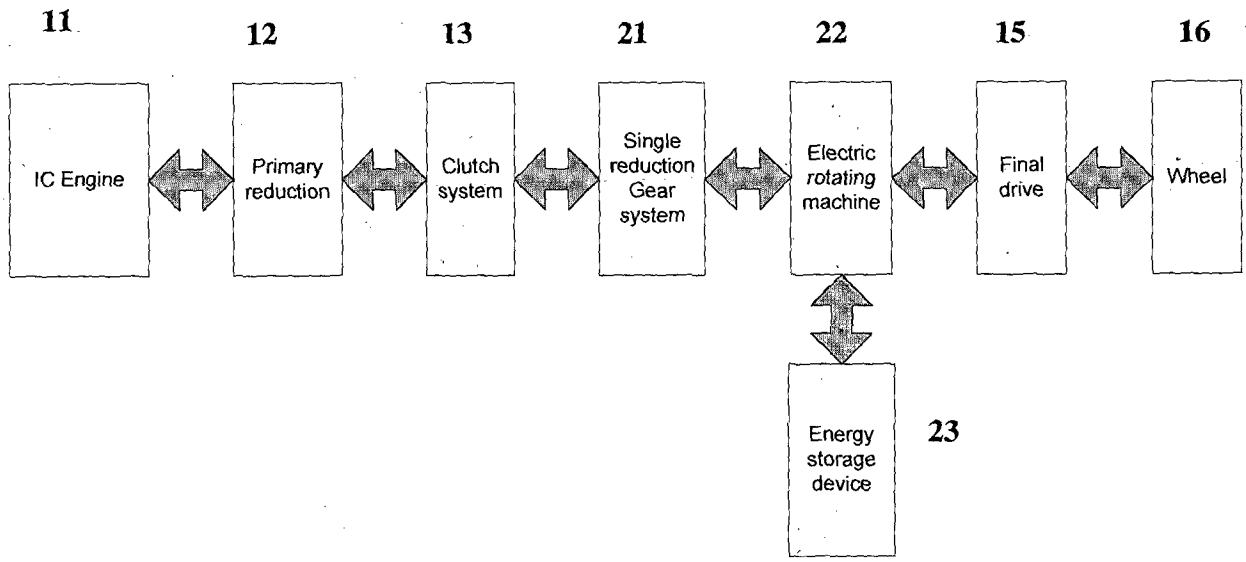


Figure 2

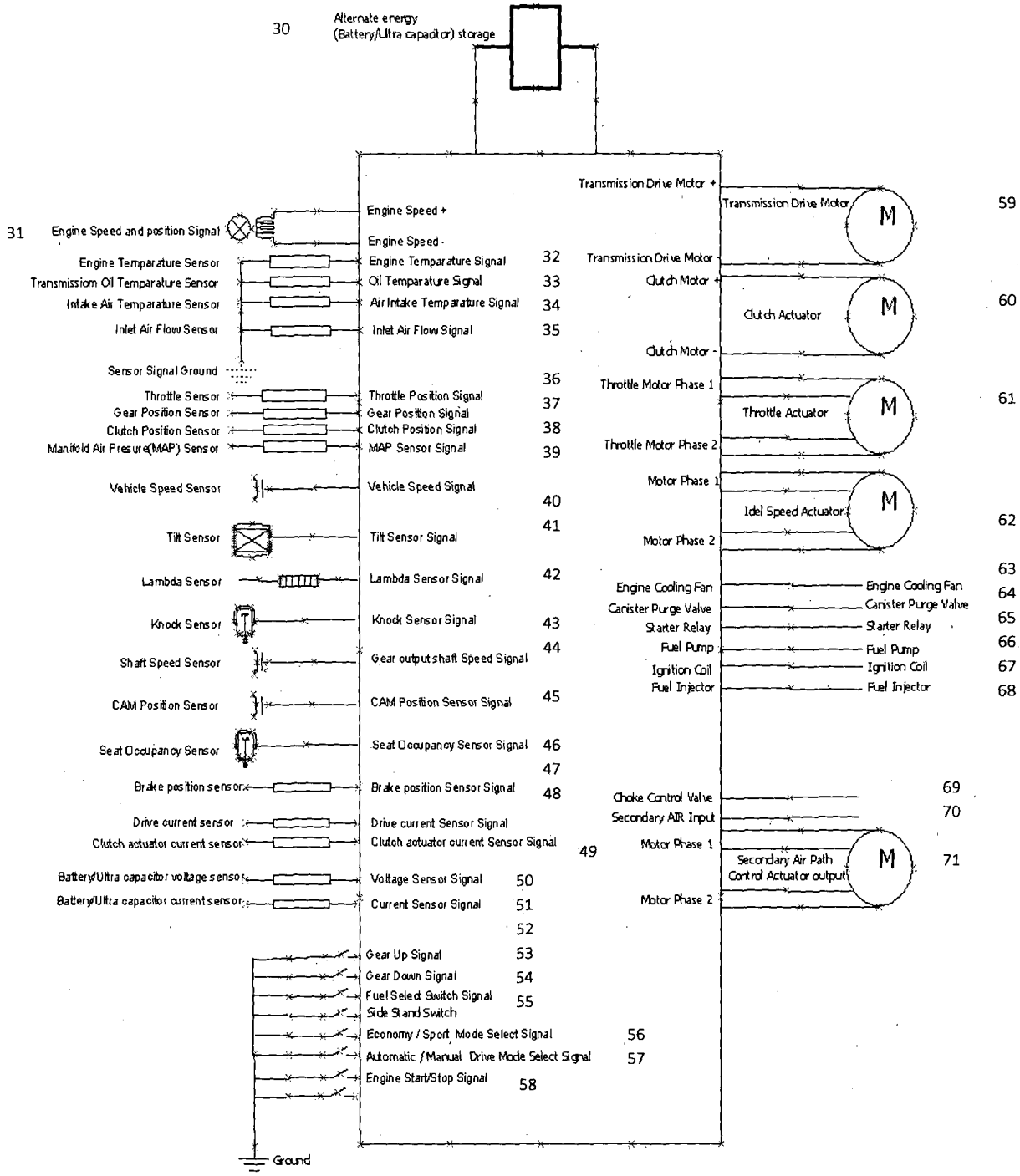

30
Alternate energy
(Battery/Ultra capacitor) storage
Engine Speed +
Engine Speed -
31
Engine Speed and position Signal
Engine Temparature Sensor
Engine Temparature Signal
32
Transmissiom Oil Temparature Sensor
Oil Temparature Signal
33
Intake Air Temparature Sensor
Air Intake Temparature Signal
34
Inlet Air Flow Sensor
Inlet Air Flow Signal
35
Sensor Signal Ground
36
Throttle Sensor
Throttle Position Signal
37
Gear Position Sensor
Gear Position Signal
Clutch Position Sensor
Clutch Position Signal
38
Manifold Air Presure(MAP) Sensor
MAP Sensor Signal
39
Vehicle Speed Sensor
Vehicle Speed Signal
40
41
Tilt Sensor
Tilt Sensor Signal
Lambda Sensor
Lambda Sensor Signal
42
Knock Sensor
Knock Sensor Signal
43
44
Shaft Speed Sensor
Gear output shaft Speed Signal
CAM Position Sensor
CAM Position Sensor Signal
45
Seat Occupancy Sensor
Seat Occupancy Sensor Signal
46
47
Brake position sensor
Brake position Sensor Signal
48
Drive current sensor
Drive current Sensor Signal
Clutch actuator current sensor
Clutch actuator current Sensor Signal
49
Battery/Ultra capacitor voltage sensor
Voltage Sensor Signal
50
Battery/Ultra capacitor current sensor
Current Sensor Signal
51
52
Gear Up Signal
53
Gear Down Signal
54
Fuel Select Switch Signal
55
Side Stand Switch
Economy / Sport Mode Select Signal
56
Automatic / Manual Drive Mode Select Signal
57
Engine Start/Stop Signal
58
Ground
Transmission Drive Motor +
Transmission Drive Motor
M
59
Transmission Drive Motor -
Clutch Motor +
Clutch Actuator
M
60
Clutch Motor -
Throttle Motor Phase 1
Throttle Actuator
M
61
Throttle Motor Phase 2
Motor Phase 1
Idel Speed Actuator
M
62
Motor Phase 2
63
Engine Cooling Fan
Engine Cooling Fan
64
Canister Purge Valve
Canister Purge Valve
65
Starter Relay
Starter Relay
66
Fuel Pump
Fuel Pump
67
Ignition Coil
Ignition Coil
Fuel Injector
Fuel Injector
68
69
Choke Control Valve
70
Secondary AIR Input
Motor Phase 1
Secondary Air Path
Control Actuator output
M
71
Motor Phase 2

Figure 3

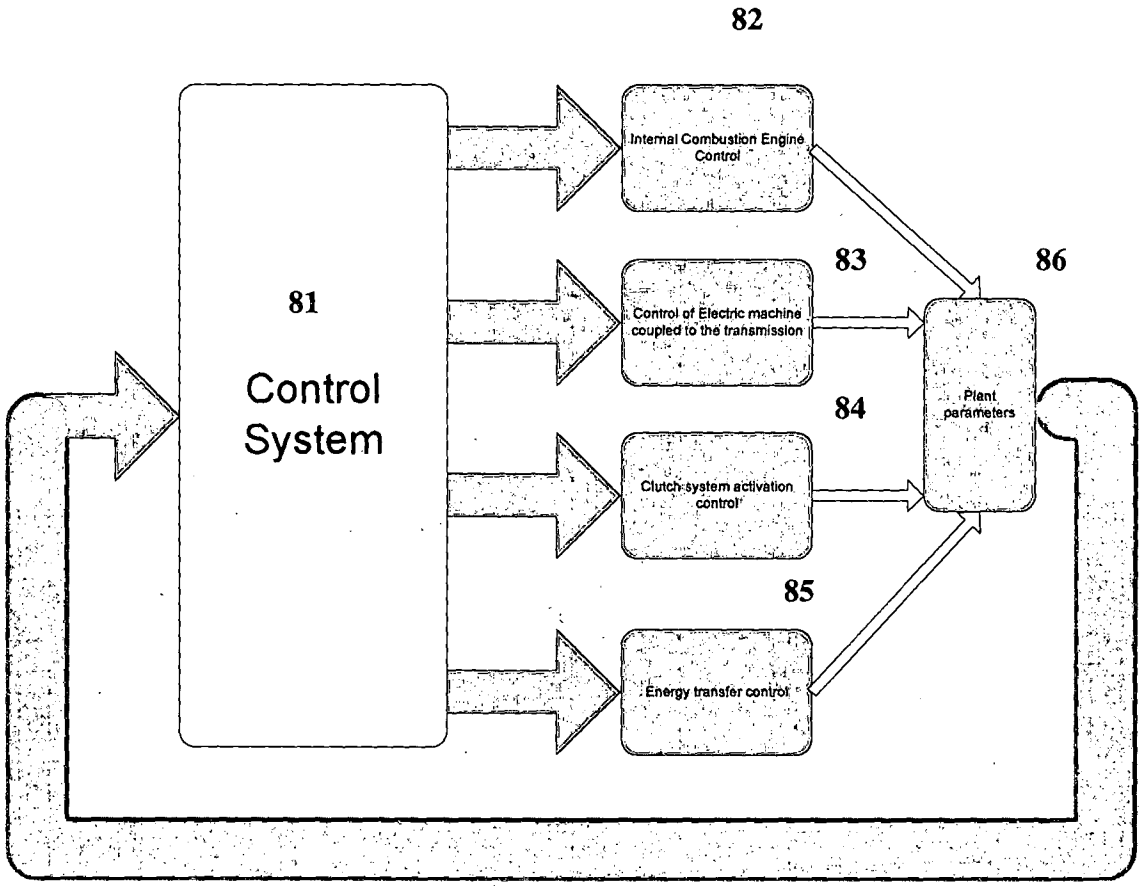

82
81
Control System
Internal Combustion Engine Control
Control of Electric machine coupled to the transmission
Clutch system activation control
Energy transfer control
83
84
85
86
Plant parameters

Figure 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IN2013/000307

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60K6/48 B60W10/08 B60W20/00
ADD.

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)
B60K B60W

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2 834 248 A1 (RENAULT [FR]) 4 July 2003 (2003-07-04) the whole document	1-10
A	US 2010/089682 A1 (MARTINI FEDERICO [IT] ET AL) 15 April 2010 (2010-04-15) the whole document	1-10
A	GB 2 483 673 A (ROMAX TECHNOLOGY LTD [GB]) 21 March 2012 (2012-03-21) the whole document	1-10
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1

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