(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 September 2013 (19.09.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/136092 A1

(51) International Patent Classification:
F02D 41/30 (2006.01) *F01N 5/02* (2006.01)

(21) International Application Number:
PCT/GB2013/050669

(22) International Filing Date:
15 March 2013 (15.03.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
12160010.0 16 March 2012 (16.03.2012) EP

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) **Title**: CONTROL SYSTEM FOR AN ENGINE ASSEMBLY

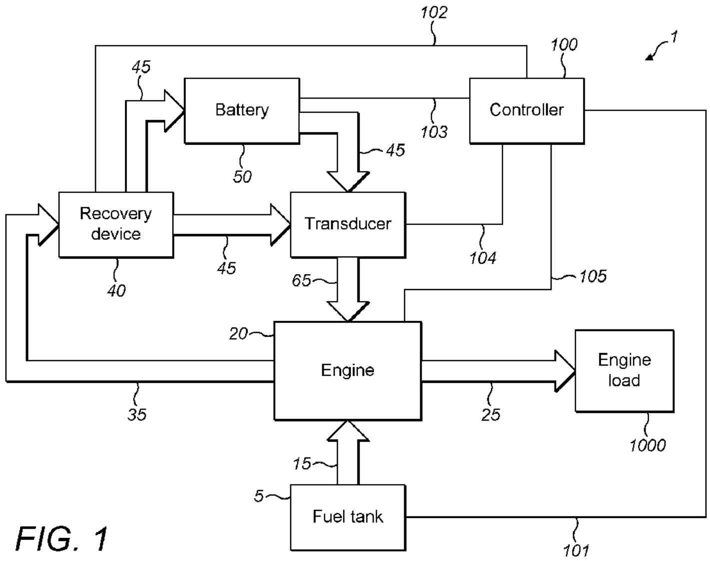

FIG. 1

(57) **Abstract**: Engines produce not only primary energy in the form of kinetic energy transmitted through a rotating crankshaft but also secondary energy which may comprise kinetic energy in other forms as well as thermal energy. In order to reduce engine running costs and increase efficiency there is a desire to make best use of all forms of energy produced by an engine. The disclosure relates to the adoption of an equivalent consumption minimisation strategy by which the engine may be controlled to derive useful energy from a first proportion of primary energy and a second proportion of secondary energy wherein the first and second proportions are selected to minimise overall energy consumption.

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Control System for an Engine Assembly

Technical Field

A control system for an engine assembly using equivalent consumption minimisation strategy.

Background

Internal combustion engines generally have efficiencies of well below 50%. Increasing energy efficiency is highly desirable for improving fuel economy, making better use of energy resources and meeting regulatory targets. Efforts to reduce fuel consumption by altering the engine and its control system to maximise the proportion of potential energy in the fuel which is converted into useful kinetic energy in the crankshaft are well known.

While these techniques are, of course, beneficial for improving engine efficiency, it is necessarily the case that an engine produces secondary forms of energy (incidental to the kinetic energy of the crankshaft) which are often not usefully employed.

Against this background, there is provided an engine assembly as disclosed herein.

Summary of the disclosure

The disclosure provides an engine assembly 1 comprising:

an engine 20 configured to convert energy in a fuel 15 into primary output energy 25 and secondary output energy 35 wherein the primary output energy 25 consists solely of primary output kinetic energy in the form of a rotating crankshaft for onward transmission to a gearbox and/or a load 1000 and the secondary output energy 35 comprises secondary output kinetic energy and secondary output thermal energy;

a recovery device 40 configured to convert the secondary output energy 35 to potential energy 45;

a transducer 60 suitable either for converting the potential energy 45 to tertiary energy 65 for conversion by the engine 20 into primary output energy 25 or for converting the potential energy 45 directly to primary output energy 25; and

a controller 100 configured to implement an equivalent consumption minimization strategy in order to control overall consumption of fuel by continuously optimising a proportion of the primary output energy 25 derived from the energy in the fuel 15 and a proportion of the primary output energy 25 derived from the potential energy 45.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Brief description of the drawings

Figure 1 is a schematic diagram showing the features and embodiment of the engine assembly of the disclosure;

Figure 2 is a schematic diagram showing example inputs and outputs of the ECMS;

Figure 3 is a schematic diagram showing an implementation of the arrangement of the disclosure;

Figure 4 is a schematic diagram showing a more specific implementation of the arrangement of Figure 3;

Figure 5 is a schematic diagram of a specific implementation of the arrangement of the disclosure.

Detailed description

Referring to Figure 1, there is illustrated an engine assembly 1 comprising an engine 20, a recovery device 40, a transducer 60 and a controller 100.

The engine 20 is configured to receive fuel 15 from a fuel tank 5 and to convert energy in the fuel into primary output energy 25 and secondary output energy 35. The primary output energy 25 may take the form of kinetic energy in a rotating crankshaft. The rotating crankshaft may be connected to an engine load 1000, perhaps via a gear box (which may or may not be considered to constitute a part of a load).

The secondary output energy 35 may comprise secondary output kinetic energy and/or secondary output thermal energy. The secondary output energy 35 may be supplied to the recovery device 40. The recovery device 40 may be configured to convert the secondary output energy 35 to potential energy 45. Optionally, the engine assembly 1 comprises a potential energy storage feature 50. Where the potential energy 45 is electrical potential energy, the potential energy storage feature 50 may be a battery.

Potential energy 45, either supplied directly from the recovery device 40 or from the potential energy storage feature 50 may be supplied to the transducer 60. The transducer 60 is suitable for converting the potential energy 45 into tertiary energy 65 for conversion by the engine 20 into primary output energy 25 (and potentially also secondary output energy 35).

The controller 100 is configured to implement an equivalent consumption minimisation strategy. This may be achieved using a data library which may be derived from offline engine modelling. Alternatively, equivalent consumption minimisation strategy may be achieved by online calculations in the engine controller. The controller 100 controls supply of fuel 15 from the fuel tank 5 to the engine 20 and supply of tertiary energy 65 from the transducer 60 to the engine 20. In particular, it controls the ratio of energy to be derived in the engine 20 from fuel 15 to energy to be derived in the engine from tertiary energy 65.

The controller 100 comprises control lines 101, 102, 103, 104 and 105 for controlling the supply of fuel, the recovery device 40, where present a battery, the transducer 60 and the engine 20, respectively. The control lines may exercise control directly or indirectly. In respect of the control of the supply of fuel 15, this may be achieved, for example, by controlling the demanded engine load on the crankshaft.

EMCS is achieved by applying a search algorithm wherein the algorithm attempts to find a minimum fuel consumption for a given set of conditions. In an online system the data resulting in minimum predicted fuel consumption would be calculated in real time. In an offline system, a model of the system would attempt to predict the best possible outcome and output it to the data library for online retrieval by the controller 100. It may be that expected drive cycles can be used to identify optimised values for the desired condition. This is particularly relevant when using an offline model.

In simple terms, the input and output of the ECMS are shown in Figure 2. The input represents the demands while the corresponding output indicates a predicted most efficient solution of X kW of energy to be derived from tertiary energy 65 and Y kW of energy to be derived from fuel 15.

In a more specific embodiment of the invention, the secondary output energy 35 may comprise secondary output kinetic energy. Specifically, the secondary output kinetic energy may comprise kinetic energy of an exhaust gas produced in the engine 20. In this case, the recovery device 40 may comprise an electric generator for converting the secondary output kinetic energy of the gas into potential energy 45 which is electrical potential energy. Electrical potential energy may or may not be transmitted to a battery for storage. In this embodiment, the transducer 60 may comprise a motor. The motor may receive potential energy 45 either directly from the electric generator or from the battery. In this embodiment, it may be that the electric generator and the electric motor are a single electric machine. Furthermore, the electric generator and electric motor (whether or not a single machine) may be part of a turbo charger.

The battery may comprise additional sources of electrical potential energy and additional drains of electrical potential energy beyond those explicitly described. That is to say, the battery may comprise inputs other than that from the recovery device 40 and outputs other than that from that to the transducer 60.

In an alternative embodiment, the recovery device 40 may comprise a thermo electric device for conversion of secondary output thermal energy. This second embodiment may or may not include a battery or other electrical potential energy storage device for storage or electrical potential energy derived in the electric device.

Other alternative embodiments fall within the scope of the appended claims. In particular, any conceivable recovery of secondary output energy 35 by means of a recovery device 40 and redeployment of that energy using a transducer 60 to provide energy back to an engine 20 for more efficient use is contemplated.

The arrangement of the disclosure recognises the significance of engines generally having significantly lower efficiencies than transmission systems to which the engine may be coupled. At the heart of the disclosure is therefore an attempt not simply to recover secondary energy which would not otherwise usefully be used, but to seek to recover that secondary energy as close to the source of that secondary energy as possible. In the case of an engine, it might, for example be the case that 70% of the energy produced constitutes secondary energy. Therefore, even if a small proportion of the 70% secondary energy can be recovered for useful use either immediately or a later time, this represents a significant energy efficiency advantage. Therefore the application of ECMS to an engine assembly may yield better efficiency improvements than when applied to a transmission system comprising an engine assembly.

Furthermore, the use of an equivalent consumption minimisation strategy allows for predicting how best to achieve a particular desired output in terms of availability of primary energy directly from the fuel and availability of primary energy derived from recovery of secondary energy via the arrangement of the disclosure. Furthermore, the strategy allows for predictions about likely future engine desired behaviour to reduce overall fuel consumption for the same benefit over an extended period.

The ECMS control techniques of the arrangement of the disclosure may be used in combination with other known control techniques including, but not limited to, fuzzy logic and feedback linearization.

Control lines 102, 103, 104, 105 may not go directly from the controller 100 to their respective engine assembly features. Instead, one or more of these control lines may go via one or more other lower level controllers for more specialised onward processing, the result of which being sent to the respective engine assembly features. Such lower level controllers include, but are not limited to an MPC or EMPC controller.

The detailed description of this disclosure has been made with respect to a small number of embodiments. The scope of the present disclosure is to be considered in light of the appended claims. It should not be inferred that one or more specific implementations of the desired description is intended to limit the scope of the claims beyond the scope of the claims themselves.

Industrial Applicability

The present disclosure provides an engine with a controller configured to implement an equivalent consumption minimization strategy in order to control overall consumption of fuel by continuously optimising a proportion of the primary output energy derived directly from the energy in the fuel and a proportion of the primary output energy derived indirectly from the energy in the fuel.

Advantageously, this may allow for overall increased engine efficiency.

CLAIMS:

1. An engine assembly comprising:

an engine configured to convert energy in a fuel into primary output energy and secondary output energy wherein the primary output energy consists solely of primary output kinetic energy in the form of a rotating crankshaft for onward transmission to a gearbox and/or a load and the secondary output energy comprises secondary output kinetic energy and secondary output thermal energy;

a recovery device configured to convert the secondary output energy to potential energy;

a transducer suitable either for converting the potential energy to tertiary energy for conversion by the engine into primary output energy or for converting the potential energy directly to primary output energy; and

a controller configured to implement an equivalent consumption minimization strategy in order to control overall consumption of fuel by continuously optimising a proportion of the primary output energy derived from the energy in the fuel and a proportion of the primary output energy derived from the potential energy.

2. The engine assembly of Claim 1, the engine assembly further comprising a potential energy storage device for storing the potential energy derived in the recovery device for possible later use by the transducer.

3. The engine assembly of Claim 2, the engine assembly 1 further comprising an output for providing potential energy from the potential energy storage device to a device outside the engine assembly.

4. The engine assembly of any preceding claim wherein the secondary output kinetic energy comprises kinetic energy of a gas, said kinetic energy of the gas being a product of conversion of the energy in a fuel into primary output energy and secondary output energy.

5. The engine assembly of any preceding claim wherein the potential energy comprises electrical potential energy.

6. The engine assembly of any preceding claim wherein the recovery device comprises an electric generator.

7. The engine assembly of any preceding claim wherein the transducer comprises an electric motor.

8. The engine assembly of Claim 7 when dependent on Claim 6 wherein an electric machine comprises both the recovery device and the transducer.

9. The engine assembly of any preceding claim wherein one or more turbo chargers comprise the recovery device and/or the transducer.

10. The engine assembly of any preceding claim wherein the recovery device comprises a thermoelectric device for conversion of secondary output thermal energy.

11. The engine assembly of any preceding claim wherein the controller outputs data to one or more further controllers for further processing to provide further processed data for controlling the engine assembly, wherein one or more of the further controllers may, optionally, implement EMPC control.

12. A method for controlling an engine assembly, the engine assembly comprising:

an engine configured to convert energy in a fuel into primary output energy and secondary output energy wherein the primary output energy consists solely of primary output kinetic energy in the form of a rotating crankshaft for onward transmission to a gearbox and/or a load and the secondary output energy comprises secondary output kinetic energy and secondary output thermal energy;

a recovery device configured to convert the secondary output energy to potential energy; and

a transducer suitable either for converting the potential energy to tertiary energy for conversion by the engine into primary output energy or for converting the potential energy directly to primary output energy;

the method comprising:

implementing an equivalent consumption minimization strategy in order to control overall consumption of fuel by continuously optimising a proportion of the primary output energy derived from the energy in the fuel and a proportion of the primary output energy derived from the potential energy.

13. The method of Claim 12 wherein implementing the equivalent consumption minimization strategy comprises either:

using a model derived data library of the controller to retrieve a value representative of a proportion of the primary output energy to be derived from the energy in the fuel and a proportion of the primary output energy to be derived from the tertiary energy in order to control overall consumption of fuel; or

performing a real time model based calculation of a value representative of a proportion of the primary output energy to be derived from the energy in the fuel and a proportion of the primary output energy to be derived from the tertiary energy in order to control overall consumption of fuel.

14. The method of Claim 12 or Claim 13 wherein the method further comprises:

obtaining either by online calculation or by retrieval from a data library a set of engine parameter values predicted to achieve a desired result using the engine to convert energy in the fuel into primary output energy; and

obtaining either by online calculation or from the data library a set of engine parameter values predicted to achieve the same desired result using the transducer to convert the potential energy to tertiary energy for conversion by the engine into primary output energy.

15. The method of any of Claims 12, 13 and 14, wherein the equivalent consumption minimization strategy provides values for control signals which determine fuel efficient strategy for a specified future period based on likely future engine assembly behaviour requirements according to the model.

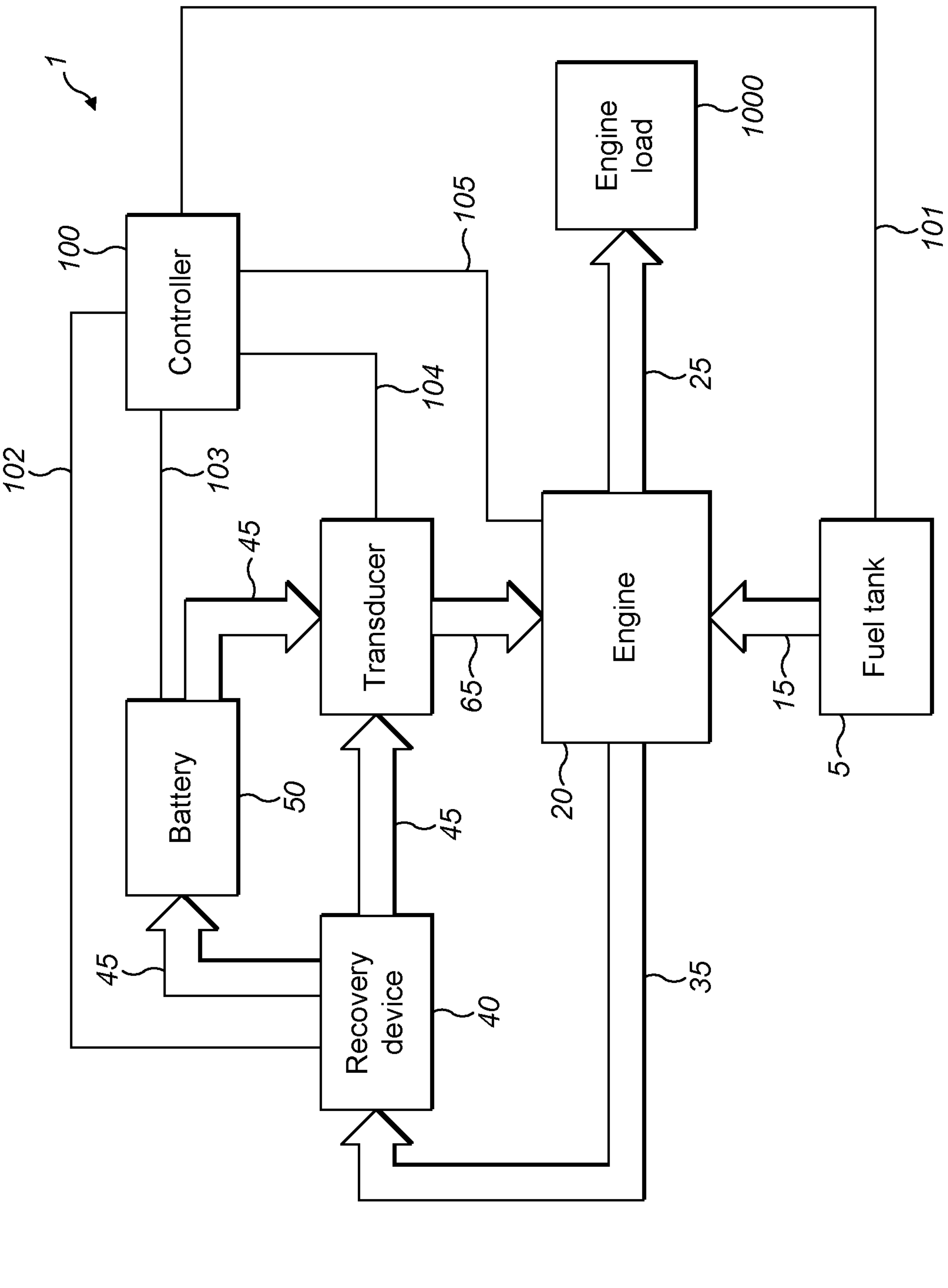
1
Controller
100
105
104
103
102
Engine load
1000
101
25
Transducer
45
65
Engine
20
Fuel tank
15
5
Battery
50
45
Recovery device
40
45
35

FIG. 1

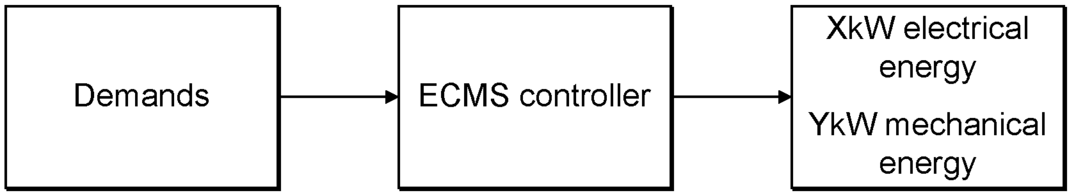

FIG. 2

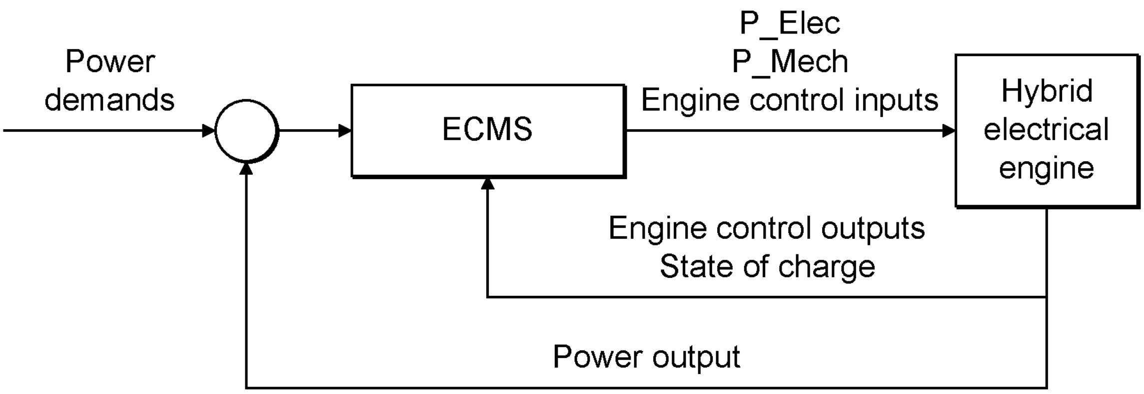

FIG. 3

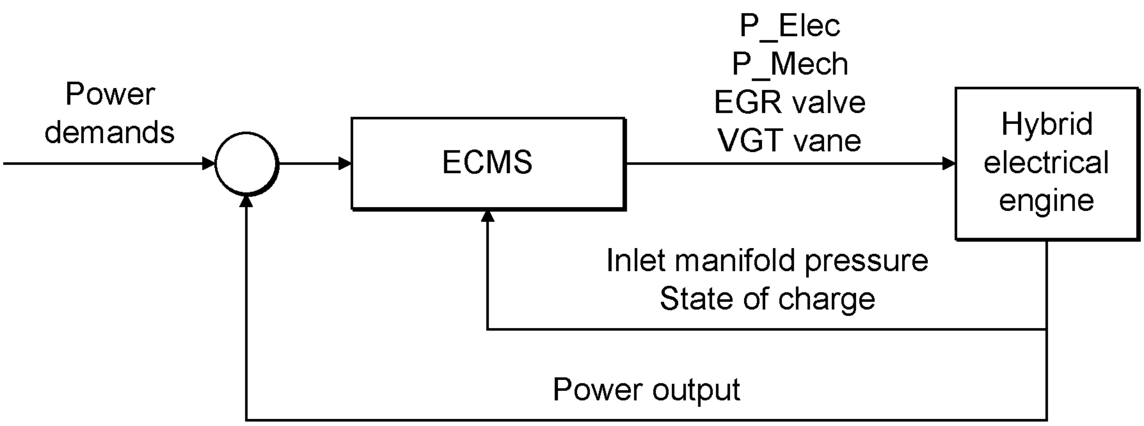

FIG. 4

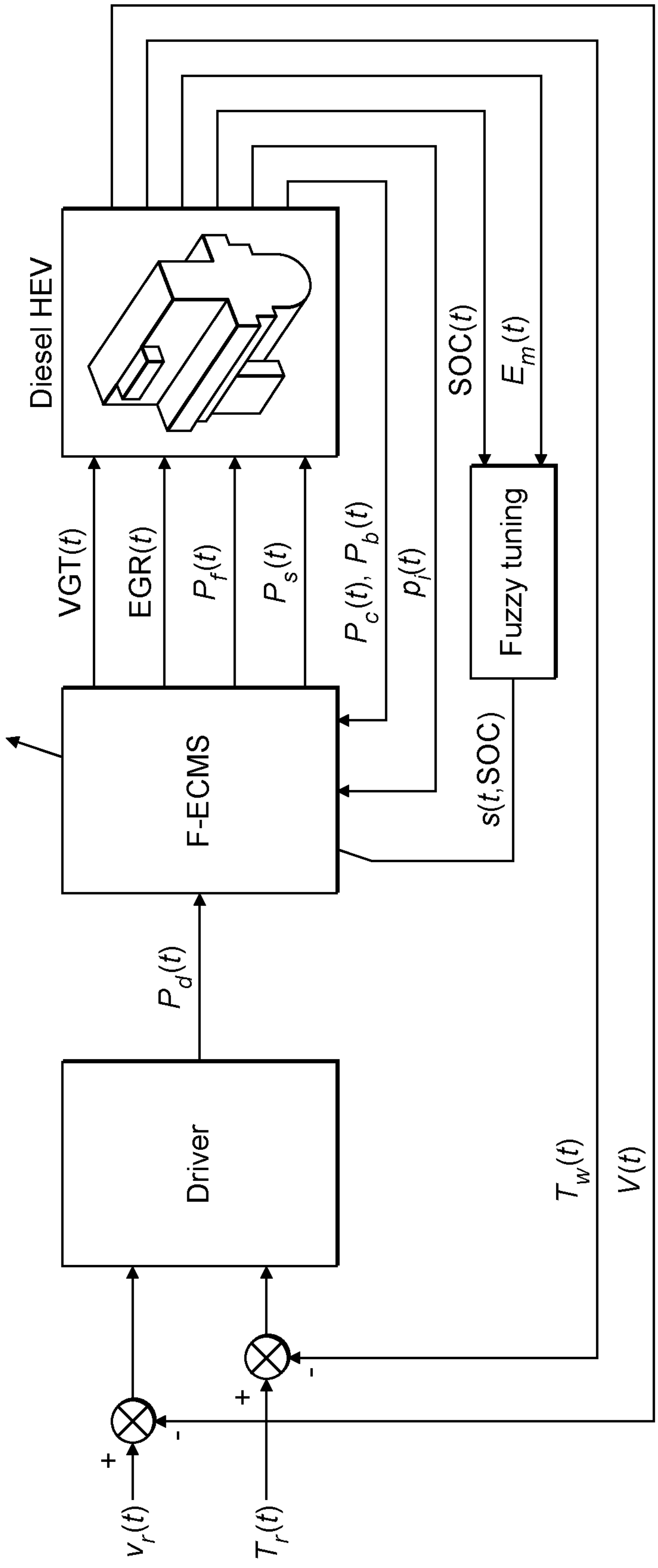
Diesel HEV
F-ECMS
Driver
Fuzzy tuning
VGT(t)
EGR(t)
P_f(t)
P_s(t)
P_c(t), P_b(t)
p_i(t)
SOC(t)
E_m(t)
s(t,SOC)
P_d(t)
T_w(t)
V(t)
v_r(t)
T_r(t)
+
-
+
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FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2013/050669

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02D41/30 F01N5/02
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)
F02D F01N

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.
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X	WO 2005/098225 A1 (TOYOTA MOTOR CO LTD [JP]; TAGUCHI TOMONARI [JP]) 20 October 2005 (2005-10-20) page 3, line 8 - page 4, line 10 page 4, line 22 - page 5, line 10 page 6, line 2 - page 9, line 18 figure 1 ----- -/--	1-15

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 April 2013	26/04/2013

Name and mailing address of the ISA/	Authorized officer
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	WO 2011/067622 A1 (RENAULT TRUCKS [FR]; AIXALA LUC [FR]) 9 June 2011 (2011-06-09) page 6, line 20 - line 25 figure 1 -----	9

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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