(12) **UK Patent Application** (19) **GB** (11) **2478333** (13) **A**

(43) Date of A Publication **07.09.2011**

(21) Application No: **1003580.6**

(22) Date of Filing: **04.03.2010**

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(51) INT CL:
B60K 1/02 (2006.01)

(56) Documents Cited:

EP 1652712 A2	**EP 1145896 A1**
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DE 003249127 A1	**FR 002809352 A1**
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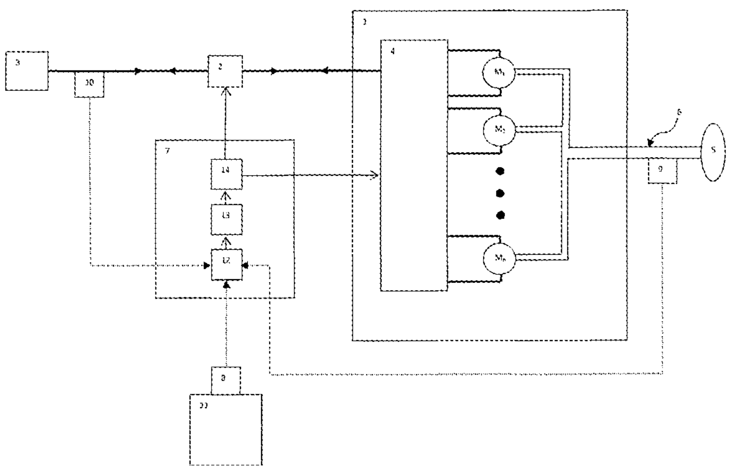
(58) Field of Search:
INT CL **B60K**
Other: **EPODOC, WPI**

(54) Title of the Invention: **Parallel & series motor**
Abstract Title: **Two or more motors operable in either series or parallel**

(57) A system comprises: two or more motors, each motor having a stator and a rotor, the rotors being mechanically coupled to a common mechanical output/input; and an electrical energy storage device electrically connected to the motors and capable of providing electrical energy to the motors and/or storing electrical energy produced by the motors; the motors being electrically interconnected so that they are capable of operating electrically in parallel or series with each other. The system may be used to convert energy between electrical and mechanical forms, to generate power from a variable force, or to drive moving parts of a machine such as a hybrid vehicle. When used in a vehicle the rotors may be coupled to a rotatable part of the drivetrain such as the crankshaft of an engine, alternatively each motor may have its rotor mechanically coupled to a wheel of the vehicle. A controller may be provided to switch the electrical connections between motors and may do this in response to data from sensors or from the position of a user input device. The electrical storage device may be a battery or a capacitor and the motors may be permanent magnet direct current type motors.

Figure 1



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PARALLEL & SERIES MOTOR

The present invention relates to a parallel/series motor system for a hybrid drive or generator.

Hybrid drive systems, in particular for automotive applications, are well known. Typically they use a single electric motor powered by an energy storage device such as a battery or a capacitor which provides electrical propulsion assistance to the vehicle engine to help reduce fuel consumption during acceleration and/or steady state driving conditions. During deceleration and/or steady state driving the surplus mechanical energy is used to charge the energy storage device through the motor, which in this mode acts as a generator.

The switching of two or more motors between parallel and series operation has previously been used for speed control, for example in automotive cooling fans which require varying degrees of cooling performance. Two motors of identical specification in series rotate at half the speed compared to the same two motors connected in parallel for a given input voltage.

In hybrid drive and variable force input generator systems however, a single motor is generally used, typically of the permanent magnet direct current type. In these motors generation performance is related to speed of rotation. Since higher speeds give higher voltage outputs, at low speeds the regeneration performance / energy recovery is lower, and hence so are the fuel savings.

The choice of motor specification in a hybrid drive must therefore generally be a compromise between good performance as a motor and as a generator; one conventional motor is not optimised for both kinds of operation.

In variable force input generator systems, such as wind turbines and tidal generators, the efficiency of energy conversion varies with the input torque so a motor system which can provide a range of modes of operation to create a large output voltage for each of a range of input torques is desirable.

Existing solutions to these problems take two forms. Complex electronics may be used to artificially increase the motor output voltage; however these are complicated and expensive. A variable speed transmission may be installed between the motor and the engine in a hybrid drive system, or the input shaft in a generator, but these tend to be bulky, taking up space and increasing the system's weight, and the moving parts involved reduce the reliability and durability of the system.

It would be desirable to increase the energy recovery / fuel savings provided by hybrid drive systems and variable force input generators by providing a more flexible yet still simple motor system. The inventive solution to the above problems of the prior art will now be described.

According to a first aspect of the present invention there is provided a system for converting energy between electrical and mechanical forms, the system comprising: two or more motors, each motor having a stator and a rotor and the rotors being mechanically coupled to a common mechanical output/input; and an electrical energy storage device electrically connected to the motors, capable of providing electrical energy to the motors and/or storing electrical energy produced by the motors; the motors being electrically interconnected so that they are capable of operating electrically in parallel or series with each other.

According to a second aspect of the present invention there is provided a power generation system for being driven by a variable force; the system comprising: two or more motors, each motor having a stator and a rotor and the rotors being mechanically coupled to a common mechanical output/input; and an electrical energy storage device electrically connected to the motors, capable of providing electrical energy to the motors and/or storing electrical energy produced by the motors; the motors being electrically interconnected so that they are capable of operating electrically in parallel or series with each other.

According to a third aspect of the present invention there is provided a hybrid drive system for driving moving parts of an item of machinery; the system comprising: two or more motors, each motor having a stator and a rotor and the rotors being mechanically coupled to a common mechanical output/input; and an electrical energy storage device electrically connected to the motors, capable of providing electrical energy to the motors and/or storing electrical energy produced by the motors; the motors being electrically interconnected so that they are capable of operating electrically in parallel or series with each other.

The item of machinery referred to above may be a vehicle. In this case the rotors may be coupled to a rotatable part of the vehicle's drivetrain. This could be, for example the crankshaft of the vehicle's engine.

If the vehicle is a road-going vehicle each motor could have its rotor mechanically coupled to a wheel of the vehicle so that their common mechanical output/input is the road.

According to any of the above aspects, the motors may be electrically interconnected such that one or more of the motors may be electrically isolated from the energy storage device whilst one or more other of the motors is electrically coupled to the energy storage device to receive electrical energy from or provide electrical energy to the storage device.

The system may further comprise a controller capable of switching the electrical interconnections between the motors between different configurations. The controller may be configured to switch between configurations of electrical interconnections of the motors in response to data from one or more sensors. The sensor or sensors could monitor the state of a user input device, mechanical energy flow between the motors and the common mechanical output/input and/or electrical energy flow between the motors and the electrical energy storage device and pass this data to the controller.

The electrical energy storage device may be, for example, a battery or a capacitor.

The motors may be permanent magnet direct current type motors.

The specification of one motor may be chosen for efficient operation as a generator and the other for efficient operation as a motor.

Preferably the motors are installed in an apparatus and the housings of the motors are rotationally fast with the structure of the apparatus in which the motors are installed.

In one embodiment, the motor arrangement as described above is installed in a hybrid vehicle in such a way that the rotors of the motors are coupled to the crankshaft of the engine by first transmission apparatus entirely borne by the vehicle, and the crankshaft and the rotors are coupled to the vehicles' wheels by second transmission apparatus entirely borne by the vehicle. In this way, the motors can drive the wheels or recover energy from them via the first and second transmission apparatus and the engine can drive the wheels via the second transmission apparatus. In another hybrid vehicle embodiment, the motor arrangement as described above is installed in a hybrid vehicle in such a way that the rotors of the motors are coupled to the vehicle's wheels by first transmission apparatus entirely borne by the vehicle, and the crankshaft is coupled to the vehicle's wheels by a separate second transmission apparatus entirely borne by the vehicle. In this way, the motors can drive the wheels or recover energy from them via the first transmission apparatus alone and the engine can drive the wheels via the second transmission apparatus. In a third arrangement the motors can be implemented in a vehicle in which an engine cannot drive the wheels directly, and only the motors can drive the wheels directly. In this third arrangement, as in the others, the motors could be wheel motors. Any of the above arrangements could be varied such that the rotors of the motors are intercoupled by transmission apparatus that is not entirely borne by the vehicle, the connection between the motors being via the wheels.

The present invention will now be described by way of example, with reference to the accompanying drawings. In the drawings:

Figure 1 is a schematic of an exemplar embodiment of the system.

Figure 2 shows a simplified circuit diagram of the switch matrix that might be used between motors in a two motor version of the system (note that connections to the rest of the system are excluded for clarity).

Figure 3 shows examples of a selection of the ways in which two motors may be mechanically coupled.

The following description is presented to enable any person skilled in the art to make and use the system, and is provided in the context of a particular application. Various modifications to the disclosed embodiments will be readily apparent to those skilled in the art.

The general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the present invention. Thus, the present invention is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features disclosed herein.

In the figures, like numerals indicate like parts.

The system shown in the figures is a multiple motor system, for use in, for example, a hybrid drive or variable force input generator, wherein the motors may be electrically connected in parallel or in series and share a common transmission shaft or have their transmission shafts mechanically coupled in some way. The system may include a controller which uses sensors to detect user input and/or the amounts of mechanical and/or electrical energy coming in and out of the motors and which responds by switching the electrical interconnections to a preferred configuration, for example to optimise output voltage in generator mode or output torque in motor mode.

As shown schematically in figure 1, the system comprises a motor unit (1), containing *multiple motors* (M_1 *to* M_n). *The housing, acting as a stator, may be fixed so as to be* rotationally fast with the structure of the apparatus in which it is installed. The individual motor housings may be joined together or separate. Each motor also has a transmission shaft, acting as a rotor, which by virtue of its rotation relative to the housing may allow for the input or output of torque to or from the motor. By mechanically coupling the transmission shafts of two or more motors together, the maximum available torque can be increased.

The motor unit (1) is electrically connected through a charge/discharge switch (2) to an electrical energy storage device (3) such as a battery or capacitor. The motors themselves are electrically interconnected via switch matrix (4). By electrically coupling two or more motors in series configuration, the maximum available output voltage can be increased. By electrically coupling two or more motors together in parallel configuration, the maximum available output current may be increased.

In the simplest embodiment there are two motors (M_1, M_2) but more may be desirable in some circumstances as this may increase the range of torques and output voltages available from the system. In embodiments with more than two motors it is possible to increase the range of outputs available, for example by interconnecting a subset of the motors in parallel with each other and connecting that subset in series with the remaining motor or motors. The number of motors used may in part be determined with regard to cost, space and weight considerations.

The motors are mechanically coupled to each other in such a way that mechanical energy is transmitted to them all from a single rotational element (5) through transmission shaft (6) when in generator mode and transmitted from them both to that single rotational element (5) (again through the transmission shaft (6)) when in motor mode. In the case of a hybrid drive system for a vehicle the rotational element (5) may be any rotating part of the vehicle powertrain. A vehicle powertrain may be broadly defined as including any component whose main purpose it is to produce or transmit mechanical drive to or from the vehicle. The connection could be indirectly or directly to rotating components of the engine, transmission system, drive shafts, axles, wheels etc. One of the simplest connection methods would be to have the motor unit adjacent to the vehicle engine and couple the motor unit to the engine using a belt drive onto the engine crankshaft.

In a simple embodiment the switch matrix (4) and/or charge/discharge switch (2) could be switched manually. Alternatively, a dynamic system that responds to current conditions could be more efficient. Therefore the system preferably includes a controller (7) which receives data from sensors (8 and/or 9 and/or 10). These, like sensor 8, may monitor the state of a user input device (11), for example such a sensor could respond to depression of the accelerator and brake pedals in a hybrid drive car. In this embodiment the controller (7) may switch the charge/discharge switch to motor mode and the switch matrix to an efficient configuration for motor operation when sensor 8 tells it that the driver has depressed the accelerator pedal; or to generator mode and an efficient configuration for operation as a generator when sensor 8 tells the controller (7) that the driver has depressed the brake pedal. In a more sophisticated embodiment the sensors 9 and/or 10 could measure the amount and direction of mechanical and/or electrical energy flow respectively in or out of the motor unit (1). Sensor 9 could be, for example, a torsion meter on the transmission shaft (6). Sensor 10 could be, for example, an ammeter or voltmeter measuring the current input/output to/from the motor unit or the potential difference across it. This data could then be processed and responded to by the controller (7) switching the switch matrix (4) in such a way as to increase efficiency of energy conversion.

Figure 1 also shows the signal paths within the controller (7). Data signals enter the input (12) from the sensors (8 and/or 9 and/or 10) and are passed to the central processing unit (13). Response signals are then passed from the central processing unit (13) to the output (14) which sends them to operate the charge/discharge switch (2) and/or the switch matrix (4).

The switch matrix (4) is shown for a system with n motors. The switch matrix (4) is controlled by the controller (7) so that it connects each of a selection of motors to the electrical energy storage device (3), and to a subset of that selection. The addition of more motors to the system dramatically increases the number of modes available. With one motor there is only one mode, with two there are four, and with three there are over fifteen.

A simplified example of how the switch matrix (4) might work for a two-motor system is shown in Figure 2. The interconnections shown allow for four possible modes of operation. For single motor operation using motor M1, switch A is closed, switch B open and switch C may be in either position. For single motor operation using motor M2, switch A is open, switch B closed and switch C set to “P”. For parallel motor operation, switch A is closed, switch B closed and switch C set to “P”. For series motor operation, switch A is open, switch B closed and switch C set to “S”.

The motors used could be all of the same size and specification, or their performance characteristics could differ. For example an advantageous arrangement in a two motor system could be to use one motor designed to perform particularly efficiently in generator mode, and another designed to perform particularly efficiently in motor mode.

Each mode may provide a different output torque for a given input voltage and current when the system is operating as a motor, and a different output voltage and current for a given input torque when operating as a generator. The controller could be used to intelligently switch between modes in response to data from the sensors in order to increase efficiency, or in a simple embodiment without sensors the operator may select a mode manually.

Figure 3 shows a selection of the many ways two motors might be mechanically connected. In every instance either the shafts of the two motors are mechanically coupled, or the motors share a common shaft. The coupling could be for example through bolting, flanges, a machined interlocking key arrangement, bushes, dampers, gears or pulleys. The blocks 15 and 16 represent the motor bodies and the blocks 17 and 18 the motor shafts. (a) shows front to back coupling where the shaft of one motor (17) is connected to the shaft of another (18) through the body of the second motor (16). (b) shows back to back coupling where the shafts of the two motors (17 and 18) are connected together through the bodies of the two motors (15 and 16). (c) shows a twin motor with a single body casing (19) containing both motor bodies (15 and 16) and connected to a single shaft (20). (d) shows front to front coupling where the two shafts (17 and 18) are connected together. (e) shows side to side coupling where the shafts of the two motors (17 and 18) are each connected to a multi-input coupling device (21) with a common output shaft (22). In each embodiment each motor has a respective housing and a respective transmission shaft, although the housings and/or the transmission shafts of the motors may be joined together.

Some example applications of the present system are in road-going vehicles such as cars, vans, Lorries, buses, coaches and motor cycles. The system could equally be applied to other forms of transport where mechanical energy is wasted and could be usefully recovered such as trains or boats. In addition the system may be used in stationary machinery with a rotating component which sometimes produces surplus mechanical energy.

The mechanical coupling between the motors need not be implemented solely through means located in or on the apparatus in which the motors are installed. For example in a road-going vehicle there could be a motor mounted on each wheel, and the mechanical connection between them would be the surface of the road. In this case as the vehicle travelled along the road the vehicle's movement would turn both motors at the same rate.

In typical embodiments the housings of the motors can be coupled rigidly or flexibly to the structure of the apparatus in which they are used, in such a way as to resist or prevent relative rotation of the housings and the structure. Thus, in a vehicle the housings of the motors could be bolted, optionally via damping mountings, to the frame of the vehicle.

Other possible applications could include a power generation system that is driven by a variable force such as wind, wave or tidal generation systems; the switching could then be implemented to best exploit the external energy available.

The motors themselves may be permanent magnet direct current type, but could also be other technologies including alternating current, direct current, brushed, brushless, permanent magnet or otherwise.

The applicant hereby discloses in isolation each individual feature described herein and any combination of two or more such features, to the extent that such features or combinations are capable of being carried out based on the present specification as a whole in the light of the common general knowledge of a person skilled in the art, irrespective of whether such features or combinations of features solve any problems disclosed herein, and without limitation to the scope of the claims. The applicant indicates that aspects of the present invention may consist of any such individual feature or combination of features. In view of the foregoing description it will be evident to a person skilled in the art that various modifications may be made within the scope of the invention.

CLAIMS

1. A system for converting energy between electrical and mechanical forms, the system comprising:

   two or more motors, each motor having a stator and a rotor and the rotors being mechanically coupled to a common mechanical output/input; and

   an electrical energy storage device electrically connected to the motors, capable of providing electrical energy to the motors and/or storing electrical energy produced by the motors;

   the motors being electrically interconnected so that they are capable of operating electrically in parallel or series with each other.

2. A power generation system for being driven by a variable force, the system comprising:

   two or more motors, each motor having a stator and a rotor and the rotors being mechanically coupled to a common mechanical output/input; and

   an electrical energy storage device electrically connected to the motors, capable of providing electrical energy to the motors and/or storing electrical energy produced by the motors;

   the motors being electrically interconnected so that they are capable of operating electrically in parallel or series with each other.

3. A hybrid drive system for driving moving parts of an item of machinery, the system comprising:

   two or more motors, each motor having a stator and a rotor and the rotors being mechanically coupled to a common mechanical output/input; and

   an electrical energy storage device electrically connected to the motors, capable of providing electrical energy to the motors and/or storing electrical energy produced by the motors;

   the motors being electrically interconnected so that they are capable of operating electrically in parallel or series with each other.

4. A system as claimed in claim 3 wherein the item of machinery is a vehicle.

5. A system as claimed in claim 4 wherein the rotors are coupled to a rotatable part of the vehicle's drivetrain.

6. A system as claimed in claim 5 wherein the rotors are coupled to the crankshaft of the vehicle's engine.

7. A system as claimed in claim 4 wherein the vehicle is a road-going vehicle.

8. A system as claimed in claim 7 wherein each motor has its rotor mechanically coupled to a wheel of the vehicle so that their common mechanical output/input is the road.

9. A system as claimed in any preceding claim wherein the motors are electrically interconnected such that one or more of the motors may be electrically isolated from the energy storage device whilst one or more other of the motors is electrically coupled to the energy storage device to receive electrical energy from or provide electrical energy to the storage device.

10. A system as claimed in any preceding claim further comprising a controller capable of switching the electrical interconnections between the motors between different configurations.

11. A system as claimed in claim 10 wherein the controller is configured to switch between configurations of electrical interconnections of the motors in response to data from one or more sensors.

12. A system as claimed in claim 11 wherein the sensor or sensors monitor the state of a user input device and pass this data to the controller.

13. A system as claimed in claim 11 or 12 wherein the sensors measure mechanical energy flow between the motors and the common mechanical output/input and pass this data to the controller.

14. A system as claimed in any of claims 11 to 13 wherein the sensors measure electrical energy flow between the motors and the electrical energy storage device and pass this data to the controller.

15. A system as claimed in any preceding claim wherein the electrical energy storage device is a battery.

16. A system as claimed in any of claims 1 to 14 wherein the electrical energy storage device is a capacitor

17. A system as claimed in any preceding claim wherein the motors are permanent magnet direct current type motors.

18. A system as claimed in any preceding claim wherein the specification of one motor is chosen for efficient operation as a generator and the other for efficient operation as a motor.

19. A system for converting energy between electrical and mechanical forms, the system being substantially as herein described with reference to the accompanying drawings.

Amendments to the claims have been filed as follows

CLAIMS

1. A system for converting energy between electrical and mechanical forms, the system comprising:

   two or more motors, each motor having a stator and a rotor and the rotors being mechanically coupled to a common mechanical output/input;

   an electrical energy storage device electrically connected to the motors, capable of providing electrical energy to the motors in a motor mode and/or storing electrical energy produced by the motors in a generator mode; and

   a switch matrix for electrically interconnecting the motors so that they are capable of operating electrically in parallel or series with each other;

   the configuration of the switch matrix and motors being arranged such that:

   the output torque on the common mechanical output/input is optimised in motor mode; and/or

   the output voltage to the electrical energy storage device is optimised in generator mode.

2. A power generation system for being driven by a variable force, the system comprising:

   two or more motors, each motor having a stator and a rotor and the rotors being mechanically coupled to a common mechanical output/input;

   an electrical energy storage device electrically connected to the motors, capable of providing electrical energy to the motors in a motor mode and/or storing electrical energy produced by the motors in a generator mode; and

   a switch matrix for electrically interconnecting the motors so that they are capable of operating electrically in parallel or series with each other;

   the configuration of the switch matrix and motors being arranged such that:

   the output torque on the common mechanical output/input is optimised in motor mode; and/or the output voltage to the electrical energy storage device is optimised in generator mode.

3. A hybrid drive system for driving moving parts of an item of machinery, the system comprising:

   two or more motors, each motor having a stator and a rotor and the rotors being mechanically coupled to a common mechanical output/input; an electrical energy storage device electrically connected to the motors, capable of providing electrical energy to the motors in a motor mode and/or storing electrical energy produced by the motors in a generator mode; and

   a switch matrix for electrically interconnecting the motors so that they are capable of operating electrically in parallel or series with each other;

   the configuration of the switch matrix and motors being arranged such that:

   the output torque on the common mechanical output/input is optimised in motor mode; and/or

   the output voltage to the electrical energy storage device is optimised in generator mode.

4. A system as claimed in claim 3 wherein the item of machinery is a vehicle.

5. A system as claimed in claim 4 wherein the rotors are coupled to a rotatable part of the vehicle's drivetrain.

6. A system as claimed in claim 5 wherein the rotors are coupled to the crankshaft of the vehicle's engine.

7. A system as claimed in claim 4 wherein the vehicle is a road-going vehicle.

8. A system as claimed in claim 7 wherein each motor has its rotor mechanically coupled to a wheel of the vehicle so that their common mechanical output/input is the road.

9. A system as claimed in any preceding claim wherein the motors are electrically interconnected such that one or more of the motors may be electrically isolated from the energy storage device whilst one or more other of the motors is electrically coupled to the energy storage device to receive electrical energy from or provide electrical energy to the storage device.

10. A system as claimed in any preceding claim further comprising a controller capable of switching the electrical interconnections between the motors between different configurations.

11. A system as claimed in claim 10 wherein the controller is configured to switch between configurations of electrical interconnections of the motors in response to data from one or more sensors.

12. A system as claimed in claim 11 wherein the sensor or sensors monitor the state of a user input device and pass this data to the controller.

13. A system as claimed in claim 11 or 12 wherein the sensors measure mechanical energy flow between the motors and the common mechanical output/input and pass this data to the controller.

14. A system as claimed in any of claims 11 to 13 wherein the sensors measure electrical energy flow between the motors and the electrical energy storage device and pass this data to the controller.

15. A system as claimed in any preceding claim wherein the electrical energy storage device is a battery.

16. A system as claimed in any of claims 1 to 14 wherein the electrical energy storage device is a capacitor

17. A system as claimed in any preceding claim wherein the motors are permanent magnet direct current type motors.

18. A system as claimed in any preceding claim wherein the specification of a first motor is chosen for efficient operation as a generator and the specification of a second motor is chosen for efficient operation as a motor.

19. A system for converting energy between electrical and mechanical forms, the system being substantially as herein described with reference to the accompanying drawings.

Figure 1

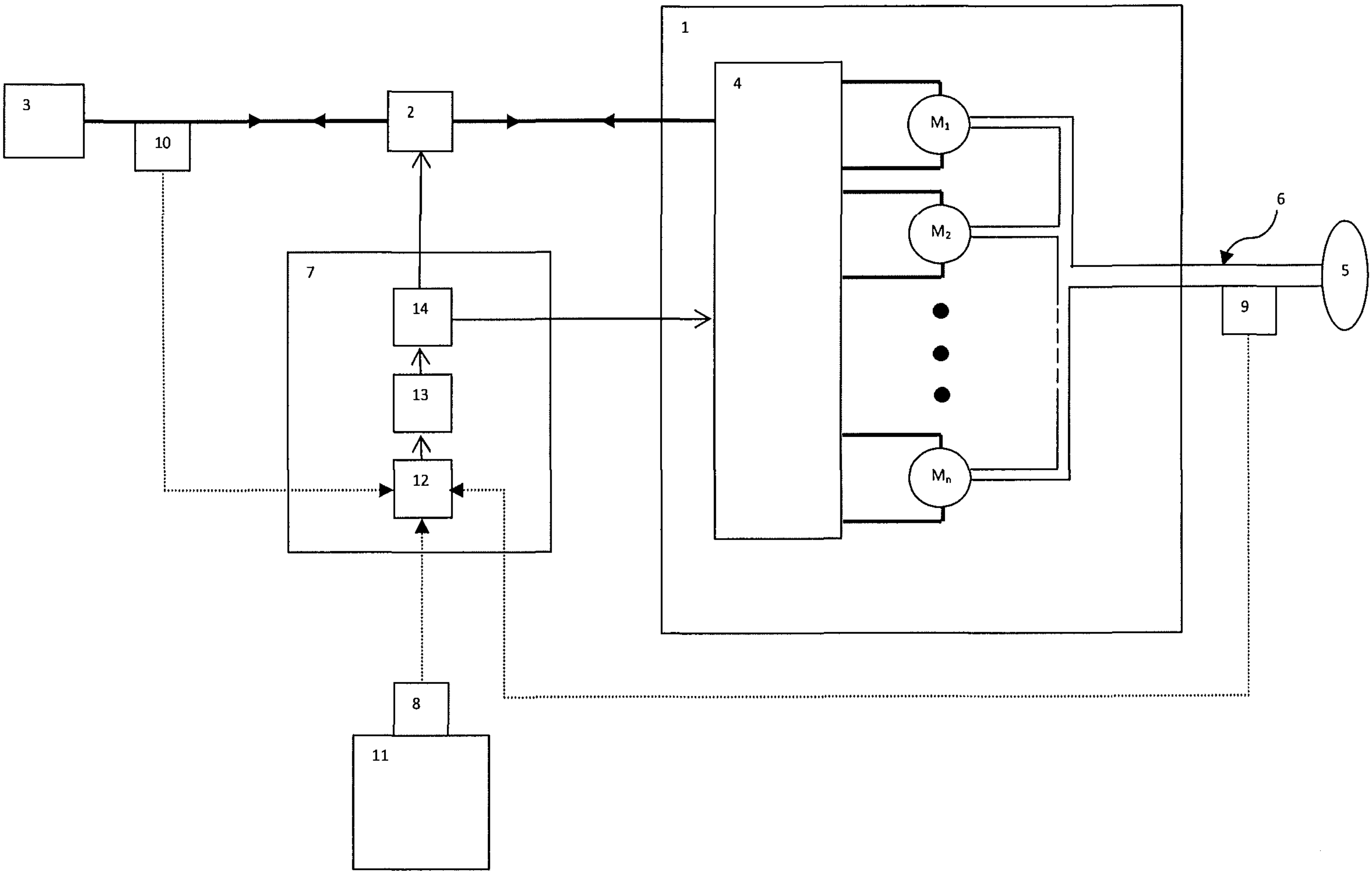


Figure 2

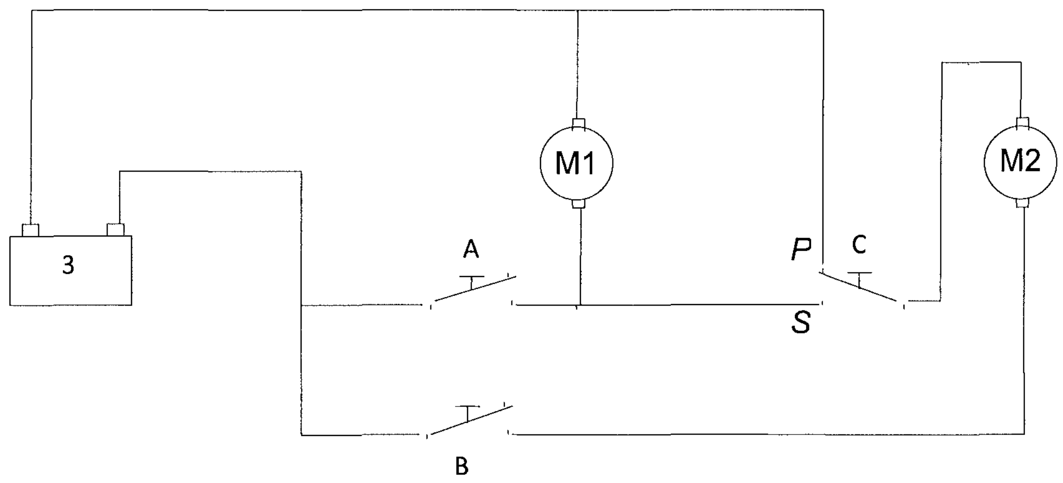
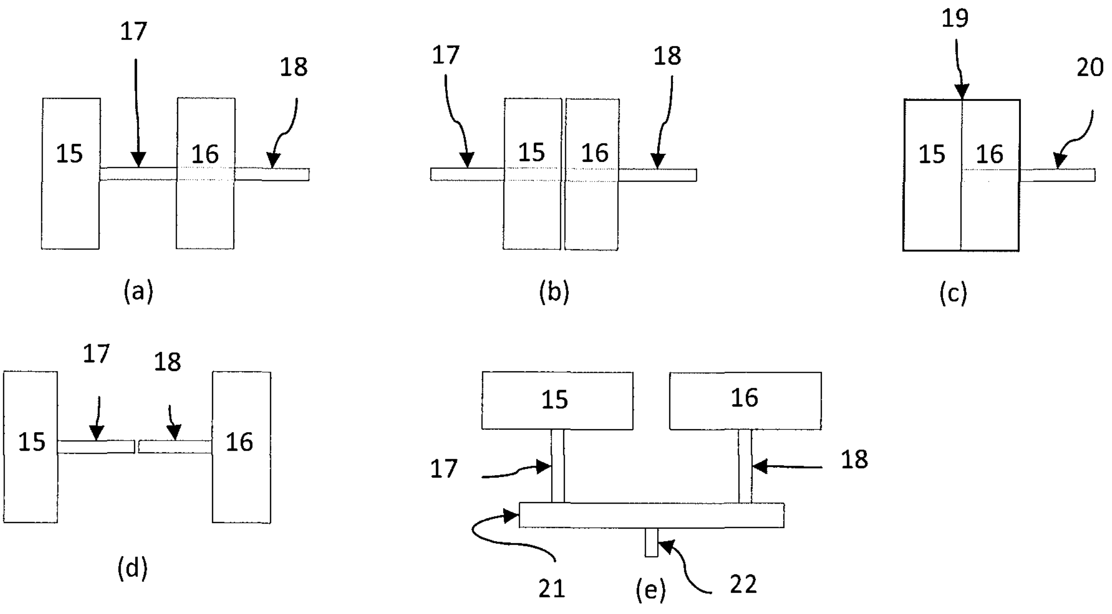


Figure 3



Application No:	GB1003580.6	**Examiner:**	Mark Boylin
Claims searched:	1-18	**Date of search:**	7 June 2011

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-7, 9-11, 15-18	EP 1652712 A2 Yang - See figures
X	1-7, 9-11, 15-18	EP 1145896 A1 Toyota - See figures
X	1-7, 9-11, 15-18	EP 1002689 A2 Fuji - See figures
X	1-7, 9-11, 15-18	FR 2809352 A1 Renault - See WPI abstract accession number 2002-099294 [14]
X	1-4, 7-11, 15-17	DE 3249127 A1 Rhein-Westfael - See figure and WPI abstract accession number 1983-765873 [38]
X	1-8, 10, 11, 15-17	CN 2769110 Y Zhao - See figures 1, 2 and 4; EPODOC abstract
X	1-4, 7-9, 15-17	NL 8503469 A Mado - See figure 1; WPI abstract accession number 1987-233242 [33]

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

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B60K

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
B60K	0001/02	01/01/2006