(12) **PATENT**

(11) **346107** (13) **B1**

(19) NO

NORWAY

(51) Int Cl.

B60K 6/50 (2007.10)
F16H 3/72 (2006.01)

Norwegian Industrial Property Office

(21)	Application nr.	20181078	(86)	International Filing Date and Application Number	
(22)	Date of Filing	2018.08.15	(85)	Date of Entry into National Phase	
(24)	Date of Effect	2018.08.15	(30)	Priority	
(41)	Publicly Available	2020.02.17			
(45)	Granted	2022.02.21			

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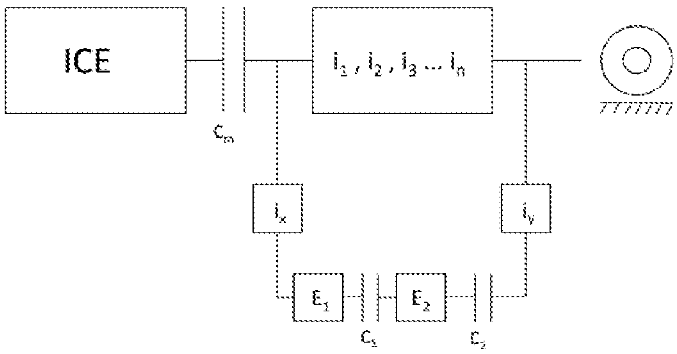
(54) Title **Transmission**

(56) References Cited: US 2006189428 A1, US 3566717 A, US 2008182693 A1, US 2008182694 A1, EP 1286082 A2, US 2009084653 A1

(57) Abstract

A transmission that have at least two different gir ratios that could be selected for transfer of mechanical power (torque and rotation) where said transmission is characterized by at least one first electric motor (E1) being connected to an input side of the transmission where an input of power is connected and at least a second electric motor (E2) being connected to an output side of the transmission, where at least the second electric motor can transfer torque to the output side of the gearbox during a change of gear ratio in the transmission.



Field of the invention

The present invention relates to transmissions and in particular transmission for a vehicle where there are a need for several gear ratios in the transmission and two electric drive motors are supporting the change of gear ratios in a way that compensate for the torque interrupt when the shift of gear ratio take place. The transmission configuration will be very useful for electric or an alternative or combined use of typically an internal combustion engine and for this invention at least two electric motors for the propulsion of the vehicle. A vehicle or drivetrain with alternative and combined use of two different type of motors for driving are commonly known as a hybrid vehicle and the drivetrain for a hybrid transmission.

Background

The invention is a new and improved electric or hybrid transmission system. Electric or hybrid transmission system is usable for a lot of different applications, all sizes of vehicles, vessels, construction machinery. Since the most common vehicles could be named as motorcycles, cars, buses and trucks this is the focus for the invention but should not be seen as a limitation for the claimed invention. Hybrid application are today most common in cars, buses and trucks. Since the pure electric version of the invention is the same as the extended version as a hybrid configuration the main focus is at the extended version.

There are many types of hybrid systems and to main types are named parallel and serial hybrid. One simple version of the parallel hybrid is the system where the electric motor is placed on one axle with wheels and the internal combustion engine ICE with transmission is placed on another axle with wheels. In another type of parallel hybrid the electric motor is attached or integrated in the main transmission. The invention is a parallel transmission of the latter type with an opportunity to run in serial hybrid mode when this is optimal.

(Detailed summary of pro’s and con’s for serial and parallel is excluded since this seems as a basic skill for the skilled in the art person, or to be included later……)

For both cars, buses and trucks it is common that hybrid systems are made by using a transmission type that is a variant of the automatic transmission already used for that vehicle type.

For cars there are two main type of automatic transmissions. The oldest technology is the automatic transmission with a planetary gear with multiple clutches that make combinations of the planetary gear ratios for the wanted gear ratio. Usually this is the type which is referred to as an automatic transmission AT. The last 20 years a type with two main clutches and gears on separate shafts (similar to the manual transmission) have also gained popularity. This is usually named as a twin clutch transmission, dual clutch transmission or Double Shift Gearbox (DSG). With an increasing number of gears the later years both of the two type of transmissions are quite expensive and complex.

For trucks the most common automatic transmission is a manual transmission that is made automatic with the use of electronically controlled actuators to operate clutches and gears instead of manual clutch pedal and manual gear levers. This represent a very energy efficient and cost optimal transmission. This type of transmission is usually named as an automated manual transmission AMT also in the cases where the transmission a have been optimised for this use and the internal parts are not used for any manual operation any more. AMT is for the moment the most common transmission in the market for the largest truck (a more detailed and specific description of this type of gearbox could be added later if necessary). The major disadvantage is that the torque will go to zero each time a change of gear is done. This is a major disadvantage for both comfort and performance of the acceleration (lost time for acceleration). Furthermore this is also a challenge for control of the ICE to meet emission standards during a change of gear.

A typical parallel hybrid system used today is an electric motor attached to the main input shaft of the gearbox of any of the AT, DSG or AMT system. Where the electric motor is designed to run with a similar rotational speed as the ICE.

Known from the patent applications are a type of transmission that tries to reduce some of the torque interrupt in AMT transmissions. Such a transmission is described in publication number: US 2004/0138800 A1 published in July 15, 2004. A variant of this with an electric motor for a hybrid drive is shown in US 2002/0082134 A1 published June 27, 2002. Such transmission is known as feasible to make and control, but had challenges with a too low torque level transferred to the output shaft during gearshift and/or a too high wear in the clutch or clutches used during the gear shift.

US 2006/189428 A1 discloses a transmission including a first and second differential gear sets, a battery, two electric machines and five selectable torque-transfer devices.

Today we see a large trend of electrification in the automotive industry. This is driven both by fuel economy, legislative, incentives, environmental motivation and the technological breakthrough in battery, fuel cell and other related technology.

(Despite the technical development there are many both practical and economic reasons that make a fully electric vehicle not the preferred choice.)

Targets:

- All power and torque from both the ICE and all the electro motor mechanical power from hybrid unit should be available at the driven wheels with best possible mechanical efficiency
- All power and torque from both the ICE and the electric motor driven hybrid unit should be available at the driven wheels through all the gears of the transmission
- The hybrid unit should be designed to perform quick gearshifts where the complete system can transfer torque during a change of gear ratio
- The hybrid system may work as a starter and generator for all or many cases for the ICE

These points add a significant customer value for the complete ICE and hybrid system.

The new and improved system will be made so that it is configurable from a system that runs mostly in the ICE driven mode to a system that could run mostly in a pure electric mode depending on the customers' requirements for function and economy. (Any further reference to any hybrid class like minimum hybrid, full hybrid, plug in hybrid could be added later if necessary).

A transmission that cannot transfer torque during the gear shift is usually a simpler and less costly transmission to provide the designed number of gear ratio steps. The automated manual transmission represents today one of the most cost effective and mechanical efficient transmissions.

The non-intuitive and inventive step that is used to optimise the system is that the electric motor of a size useable for electric drive have a cost that is very proportional with the torque and mechanical power performed by the motor. This means that the cost is very little changed if the electric motor is one unit or two units. (more explanation could be added if necessary) But functionally there is a large difference since two electric motors could perform functionally to a large extent like a mechanical gearbox by transforming a lower torque at high rpm (rotational speed) to a higher torque at a lower rpm. Since the electric motor are able to perform with a much higher mechanical power output in short time periods this performance fits very well with the need during a gear shift which is a relatively short time typically less than 2-3 seconds.

The inventive step is further increased by the mechanical connections connecting a second electric motor to input shaft or output shaft or both. With at least one such connection being a clutch the hybrid system will be able to simultaneously transfer both mechanical power from input shaft to output shaft with electric and/or mechanical power directly additional when needed. The system will also be able to perform even better transfer of torque with the use of the kinetic energy stored or possible to store in the rotational parts of the system. Since electric motors have a substantial rotational inertia this effect could be used to increase the torque to the output shaft of the gearbox during a gearshift.

The new invention where at least two electric motors are in use in the hybrid system will therefor increase the complete performance of the transmission system since it makes it possible for an AMT transmission to transfer torque during gearshift. This is important to perform the best possible acceleration, keep speed during uphill driving, comfort, minimize emissions during gearshifts and give an overall good efficiency. By using the two electric motors in this hybrid system the behaviour will be like what is usual only with more complex and expensive transmission systems (AT or DSG). For trucks this means a significant increase in customer value and modular way of building the transmission that will be an attractive solution for the truck manufacturer especially. For cars this means a substantially reduced component cost by not requiring an expensive transmission with torque transfer during shift of gear ratios.

(In many cases an electric motor that operate at a different rotational speed than the typical internal combustion engine could reduce the cost of the electric motor. This is one of the arguments for not having the electric motor concentric attached to the input shaft of the gearbox. Another argument for having the first electric motor in parallel with the main gearbox is the target to have the shortest possible build length of the complete transmission.)

Summary of the invention:

The invention is defined by the appended set of claims.

The invention relates to a vehicle, a vehicle transmission system or a transmission system for a vehicle, that at least part of the time can be driven with only electric motors and where it is possible to use the at least two electric motors through several gear ratios. The inventive transmission system has two parallel shaft systems for transferring the torque to the driven wheels. The first shaft system with multiple gears and typically being a layshaft gearbox with zero torque being transferred during a gearshift. In normal driving mode mechanical power will usually run through the first shaft system since this will provide the optimal gear ratio with the highest efficiency and to the lowest cost. The second shaft system goes in parallel with said gearbox and being able to transfer torque to the driven wheels during a shift of gear ratios. The transfer of torque takes place with both of the two electric motors as well as the two or more clutches in the system. The invention is particularly useful for a hybrid system where an internal combustion engine at least for part of the time may give at least some of the power for the propulsion of the vehicle. When an internal combustion engine is part of the system maximum efficiency is obtained by having many gear ratios available for transfer of the power to the driven wheels.

During a shift of gear ratio the two electric motors will use its peak power performance only available in shorter time periods to compensate. The second shaft system will be able to transfer torque over the two clutches and at the same time receive mechanical power at the first electric motor and transfer electric power to the second electric motor that will supply mechanical power to the driven wheels through the second clutch during a gearshift. Additionally, the torque to the driven wheels could be boosted by electricity from a battery or other electric source. The system can when possible and useful also use the kinetic energy stored in the rotational parts to boost the power to the driven wheels.

In an electric drive situation, the most normal situation will be that the first clutch will be fully engaged to transfer torque and that the second clutch will be fully open and not transfer any torque.

In other words, the present invention provides a transmission (e.g. a transmission system for a vehicle or a transmission system comprising a gearbox) that have at least two different gear ratios that can be selected for transfer of mechanical power (torque and rotation), i.e. a power transmission, where said power transmission is characterised by comprising a first electric motor (E_1) connected to an input side of the power transmission, where an input of power is connected, and to an output side of the power transmission via a first clutch (C1) and a second electric motor (E_2), the second electric motor (E2) is connected to the output side of the power transmission via a second clutch (C2) and to the input side of the power transmission via the first clutch (C1) and the first electric motor (E1), wherein at least the second electric motor can transfer torque to the output side of the power transmission during a change of gear ratio in the power transmission.

The transmission may further be characterised in that the at least one first electric motor (E_1) is connected to an input side of the transmission (or to an input side of a main gearbox (i1,i2..) of the transmission system) where an input of power is connected optionally via at least one intermediate gear (is1,is2), and at least a second electric motor (E_2) being connected to an output side of the transmission (or to an output side of a main gearbox (i1,i2..) of the transmission system), the output side optionally connected to drive wheels via at least one gear (ir1,ir2), where at least the second electric motor can transfer torque to the output side of the gearbox during a change of gear ratio in the transmission.

In one embodiment, the transmission has at least two different gear ratios that could be selected for transfer of mechanical power (torque and rotation) where said transmission have on the input side connected an engine that are not able to produce torque at standstill meaning no rotational speed characterised by at least one first electric motor is connected to the side where the input of power is connected and at least a second electric motor is connected to the output side of the transmission where at least the second electric motor can transfer torque to the output side of the gearbox during a change of gear ratio in the transmission.

In one embodiment of the transmission, the at least the first electric motors can in another driving situation be connected to the input side (shaft) of the transmission and could use the transmission to transfer torque to the output side through the changeable gear ratios.

In one embodiment of the transmission, the at least two electric motors are connected to an energy storage or source.

In one embodiment of the transmission, the energy storage or source is an electric battery, electric capacitor, fuel cell or a connection to the electric network outside of the vehicle, or any combination thereof.

In one embodiment of the transmission, the first electric motor is connected to the input side of the transmission and the second electric motor is additionally connected to the input side with a connection able to transfer torque and rotation.

In one embodiment of the transmission, the connection between input side and second electric motor could be operated to transfer at least two different levels of torque between zero and maximum torque possible in the system.

In one embodiment of the transmission, the connection between first and second electric motor could be operated with a torque level controllable between zero and a maximum torque level.

In one embodiment of the transmission, the second electric motor could be connected and disconnected to the output side of transmission.

In one embodiment of the transmission, the connection between second electric motor and output side of transmission could be operated with a torque level controllable between zero and a designed torque level.

In one embodiment of the transmission, a torque is transferred from input side of transmission to the output side of the transmission characterised by a simultaneous transfer of electric power from at least a first electric motor to a second electric motor with or without simultaneous energy being transferred to said energy store.

In one embodiment of the invention, any rotational kinetic energy is used to give an increased or decreased torque level at the input or output side of the gearbox.

In one embodiment of the invention, at least the kinetic energy in the second electric motor gives an increased positive or negative torque to the output side of the transmission.

In one embodiment of the invention, the ability to increased or decreased power by the kinetic energy is used during a change of gear ratio.

In one embodiment of the invention, the highest level of use or capture of the kinetic energy is in the situation where the mechanical connection of the gear is disengaged or engaged during a change of gear ratio.

In one embodiment of the invention, the rotational speed is intentionally increased or decreased in a time in advance to further boost or capture of the kinetic energy applied on the system.

In one embodiment of the transmission, a part of the transmission ratio is arranged between an engine that are not able to produce torque at standstill meaning no rotational speed and the point where at least a first electric motor is connected.

In one embodiment of the invention, the part of the transmission ratio is a changeable gear ratio.

In one embodiment of the transmission, a part of the transmission ratio is arranged between the second electric motor and a changeable gear ratio arranged at or connected to the output of transmission.

In one embodiment of the transmission, the engine that are not able to produce torque at standstill meaning no rotational speed is an internal combustion engine.

In one embodiment of the transmission, the controllable connections are controllable clutches.

In one embodiment of the transmission, the controllable clutch is of a friction type

In one embodiment of the transmission, at least one controllable clutch is of a type that can increase the torque by speed difference over the clutch.

In one embodiment of the transmission, at least one controllable clutch is transferring torque from the ICE (internal combustion engine) to the output shaft during a change of gear ratio.

In one embodiment of the transmission, the effect of increasing the torque at the output shaft is supported at the same time by any of the described methods: electrically by the electric motors, mechanical by clutches or use of the kinetic energy in the rotational parts.

In one embodiment of the transmission, the transmission comprises a transmission of the type normally used with manual transmission or automated manual transmission in many cases called a layshaft gearbox.

In one embodiment of the transmission, the first electric motor is used to control the rotational speed of the input shaft to the correct speed before the next gear is engaged mechanically which may reduce the need for costly synchronizer rings.

Description of the drawings:

Fig. 1: The figure shows a known and typical way to show a manual or automated manual transmission as a block diagram. ICE (internal combustion engine) is typically a gasoline or diesel engine. Where the start-up clutch or main clutch C_m is typically a frictional type of clutch and the gear ratios (i_1, i_2...) are usually engaged mechanical and only one at the same time. The torque in the gearbox will have to be zero at every gearshift and this also make the gearshift slow. This is a huge disadvantage for comfort, performance, emission control and fuel economy.

Fig. 2: Shows a block diagram of the well-known transmission usually named as a twin clutch transmission, dual clutch transmission or Double Shift Gearbox (DSG). This can alternatively shift between the two parallel gear sets to transfer the torque

to the driven wheels (the wheels illustrated as a double circle). This gives the opportunity to have continues torque transfer during gearshifts. To have essentially two gearboxes in one unit this transmission type is quite expensive and mechanical complex.

Fig. 3: Shows a known transmission lay out for a hybrid system used in heavy trucks and busses where the electric motor E_h is attached to the input shaft of an AMT transmission. The big disadvantage will be the same as for the automated manual transmission shown in Fig. 1.

Fig. 4: Is essentially the same functionality, the electric motor E_l is attached in parallel with the gearbox and with the possibility for being geared by ratio i_x to a more cost optimal design than figure 3.

Fig. 5: Shows a block diagram of the new invention where the two electric motors E_1, E_2 and the two clutches C_1,C_2 can transfer torque in a shaft parallel to the main gearbox. This gives the opportunity to transfer torque during a gearshift. The inventive step by using the electric motors for this in combination with clutches is not known from before. Electric motors are known to be able to give a significantly higher torque and power for a short time and using this feature further increase the strength of the inventive step. Even more difficult to imagine even for the skilled engineer is the fact that the two clutches and two electric motors gives a significant further increased torque transfer performance by using the rotational kinetic energy in the system during the gearshifts.

Fig. 6: Shows a version of the new invention where no internal combustion engine is connected in the system. Especially for vehicles that will need to run longer periods in both at highway speed as well as longer periods at very low speed there are also for fully electric vehicles cases where gear might be an advantage. Also for this case it will be then be possible to shift gears without torque interrupt.

Fig. 7: Shows a more detailed schematic of the block diagram in figure 5. The gearbox shown in this schematic is a layshaft gearbox with 5 gears forward and 1 reverse gear. The lay shaft gearbox in this case could be made without synchronizers which further reduce the cost of the gearbox and increase the robustness. Typical for a layshaft gear box is the use of two parallel shafts and the use of a splined sleeve that connects the selected gear to the shaft so that torque can be transferred. These gearboxes are known as the transmission with the highest efficiency and the lowest cost when multiple gear ratios are needed.

Fig. 8: Is the new invention with same functionality as fig. 7 but with a small change in the mechanical layout so that the two clutches are placed in the same area

and give a better integration for both clutches and the clutch actuators. In addition, this also provides more space for the electric motors and clutches in the length direction.

Fig. 9: Is the new invention with same functionality and the same mechanical lay out as fig. 7. Shown in fig. 9 is the fact that this invention need to be electronically controlled on actuation of all the 3 clutches as well as all the gearshift actuation. The actuation may be of any electronical controllable method including electro motoric, electric solenoid, electro hydraulic or pneumatic methods.

Fig. 10: Showing electronic control of all actuation for the fig. 8 mechanical layout.

Fig. 11: Showing a mechanical layout where the E_1 motor is placed concentric and fixed to the input shaft

Fig. 12: Showing a mechanical layout where a part of the transmission is placed before and/or after the parallel system that transfer torque during a gearshift

Brief description (example) of a positive torque upshift control strategy:

1. $E_1 + E_2$ is running engaged rotational with input shaft of the gearbox. C_1 closed and C_2 open.
2. Torque in $E_1 + C_1$ is controlled to be equal to torque in C_m. (at least C_1 is slipping) Torque is transferred to the driven wheels by engaging a slipping C_2. Additional info: Torque in C_2 will be typically higher than in the C_1, because of torque from the E_2 and the kinetic energy in the E_2 is used when braking this down in speed.
3. Low gear is disengaged
4. Input shaft speed is reduced by torque higher in $E_1 + C_1$ than in C_m.
5. When inputs shaft speed is synchronous with the new and higher gear and the torque in $E_1 + C_1$ is controlled to be equal to torque in C_m then step 6 could be performed.
6. New higher gear could be engaged. Additional info: Torque in C_2 will be typically higher than in the C_1, because of torque from the E_2 and the kinetic energy in the E_2 is used when braking this down in speed.
7. The full torque from the ICE is established in the C_m.

In addition, it will also be possible to use kinetic energy from the ICE during step 2 to 6 to further increase the transferred torque during the gearshift. But this will require a more detailed control of clutch C_m and the ICE. But this is a very likely control strategy added to the basic control strategy described above.

The control strategy will also change depending on the % of torque requested from the driver/cruise control or other input. Typically, most of the torque during a gear shift will be transferred over the two electric motors, if these two motors can keep up with the torque demand from the system. This will reduce heat and wear in the clutches in the system.

Claims

1. A power transmission that have at least two different gear ratios that can be selected for transfer of mechanical power (torque and rotation) where said power transmission is
characterised by comprising a first electric motor (E_1) connected to an input side of the power transmission, where an input of power is connected, and to an output side of the power transmission via a first clutch (C1) and a second electric motor (E_2), the second electric motor (E2) is connected to the output side of the power transmission via a second clutch (C2) and to the input side of the power transmission via the first clutch (C1) and the first electric motor (E1), wherein at least the second electric motor can transfer torque to the output side of the power transmission during a change of gear ratio in the power transmission.

2. The power transmission according to claim 1, wherein the first electric motor (E1) and the second electric motor (E2) can transfer torque to the input side of the power transmission via the first clutch (C1) when the second clutch (C2) is open.

3. The power transmission according to claim 1 or 2, wherein the first electric motor (E1) can transfer torque from the input side of the power transmission to the output side of the power transmission via the first clutch (C1), the second electric motor (E2) and the second clutch (C2).

4. The power transmission according to any of claims 1-3, wherein the first and second electric motors (E1,E2) are connected to an energy storage or source.

5. The power transmission according to claim 4 wherein the energy storage or source is an electric battery, electric capacitor, fuel cell or a connection to an electric network outside of a vehicle, or any combination thereof.

6. The power transmission according to any of claims 1-5, wherein the connection between the input side and the second electric motor may be operated to transfer at least two different levels of torque between zero and maximum torque possible in the system.

7. The power transmission according to any of claims 1-6, wherein the first clutch (C1) may be operated with a torque level controllable between zero and a maximum torque level.

8. The power transmission according to claim 4 or 5, wherein torque may be transferred from the input side of the power transmission to the output side of the power transmission by transfer of electric power from the first electric motor (E1) to the second electric motor (E2) without energy being simultaneously transferred to the energy storage.

9. The power transmission according to any of the preceding claims, comprising an internal combustion engine (ICE) connected to the input side of the power transmission via a third clutch (Cm).

10. The power transmission according to claim 8, wherein the third clutch (Cm) may transfer torque from the ICE to the output side of the power transmission during a change of gear ratio.

Krav

1. En kraftoverføring som har minst to forskjellige girutvekslinger som kan velges for overføring av mekanisk kraft (moment og rotasjon) hvor nevnte kraftoverføring er
karakterisert ved å omfatte en første elektrisk motor (E_1) koblet til en tilførselsside av kraftoverføringen, hvor en krafttilførsel er tilkoblet, og til en uttaksside av kraftoverføringen via en første clutch (C1) og en andre elektrisk motor (E_2), den andre elektriske motoren (E2) er koblet til uttakssiden til kraftoverføringen via en andre clutch (C2) og til tilførselssiden til kraftoverføringen via den første clutchen (C1) og den første elektriske motoren (E1), hvor minst den andre elektriske motoren kan overføre moment til uttakssiden til kraftoverføringen under et girutvekslingsbytte i kraftoverføringen.

2. Kraftoverføringen ifølge krav 1, hvor den første elektriske motoren (E1) og den andre elektriske motoren (E2) kan overføre moment til tilførselssiden til kraftoverføringen via den første clutchen (C1) når den andre clutchen (C2) er åpen.

3. Kraftoverføringen ifølge krav 1 eller 2, hvor den første elektriske motoren (E1) kan overføre moment fra tilførselssiden til kraftoverføringen til uttakssiden til kraftoverføringen via den første clutchen (C1), den andre elektriske motoren (E2) og den andre clutchen (C2).

4. Kraftoverføringen ifølge hvilket som helst av kravene 1-3, hvor den første og den andre elektriske motoren (E1,E2) er koblet til et energilager eller energikilde.

5. Kraftoverføringen ifølge krav 4 hvor energilageret eller energikilden er et elektrisk batteri, en elektrisk kondensator, brenselcelle eller en kobling til et elektrisk nettverk utenfor et kjøretøy, eller enhver kombinasjon derav.

6. Kraftoverføringen ifølge hvilket som helst av kravene 1-5, hvor koblingen mellom tilførselssiden og den andre elektriske motoren kan drives for å overføre minst to nivåer av moment mellom null og maksimalt moment mulig i systemet.

7. Kraftoverføringen ifølge hvilket som helst av kravene 1-6, hvor den første clutchen (C1) kan drives med et moment som er regulerbart mellom null og et maksimalt moment.

8. Kraftoverføringen ifølge krav 4 eller 5, hvor moment kan overføres fra tilførselssiden til kraftoverføringen til uttakssiden til kraftoverføringen ved overføring av elektrisk kraft fra den første elektriske motoren (E1) til den andre elektriske motoren (E2) uten at energi samtidig blir overført til energilageret.

9. Kraftoverføringen ifølge hvilket som helst av de forutgående kravene, omfattende en forbrenningsmotor (ICE) koblet til tilførselssiden til kraftoverføringen via en tredje clutch (Cm).

10. Kraftoverføringen ifølge krav 8, hvor den tredje clutchen (Cm) kan overføre moment fra forbrenningsmotoren til uttakssiden til kraftoverføringen under et girutvekslingsbytte.

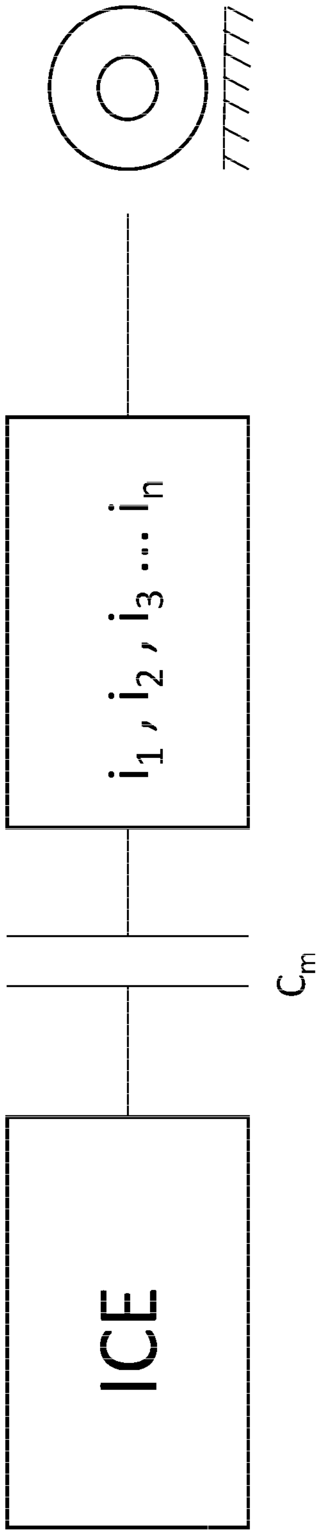


Fig. 1

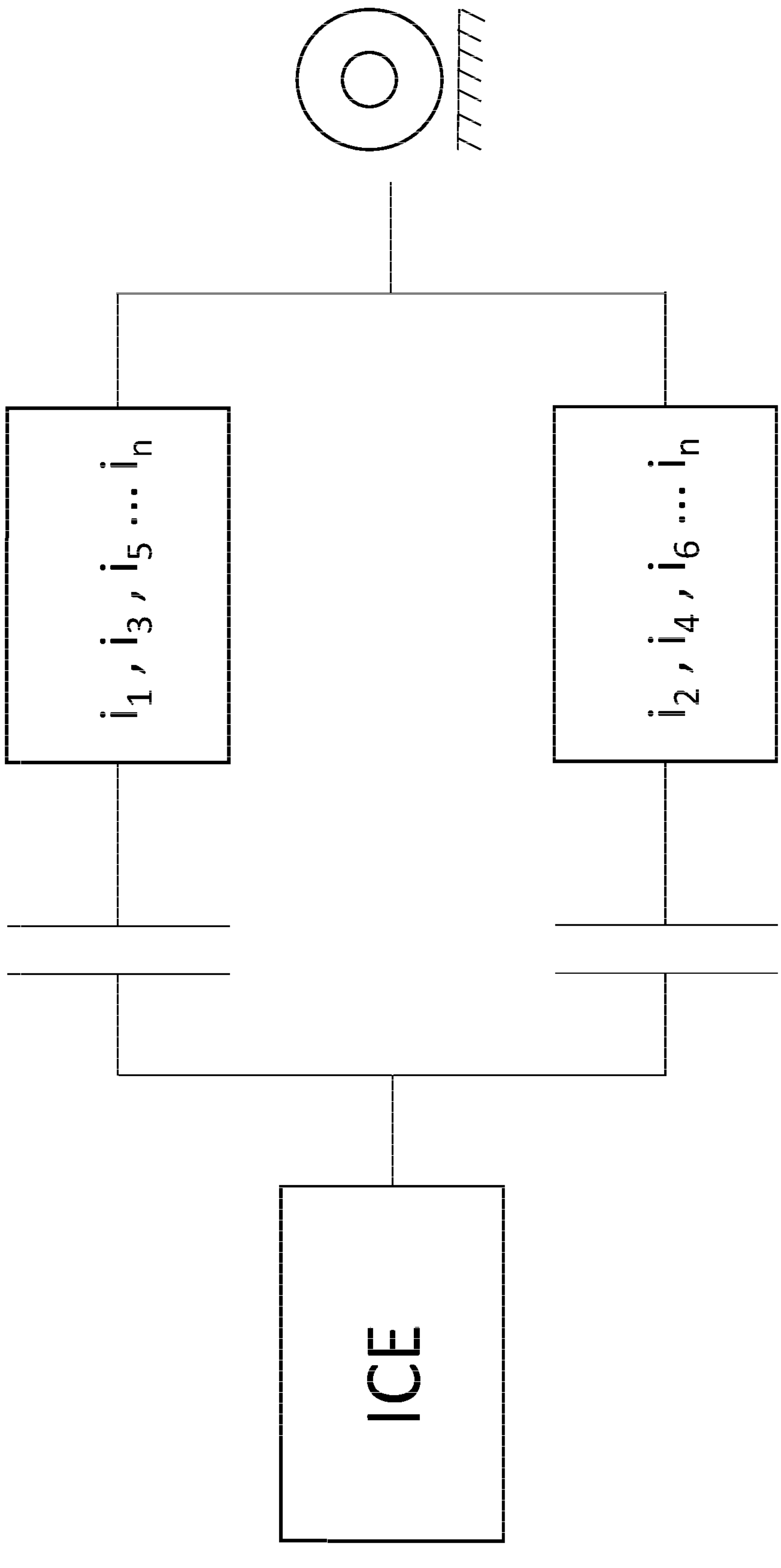


Fig. 2

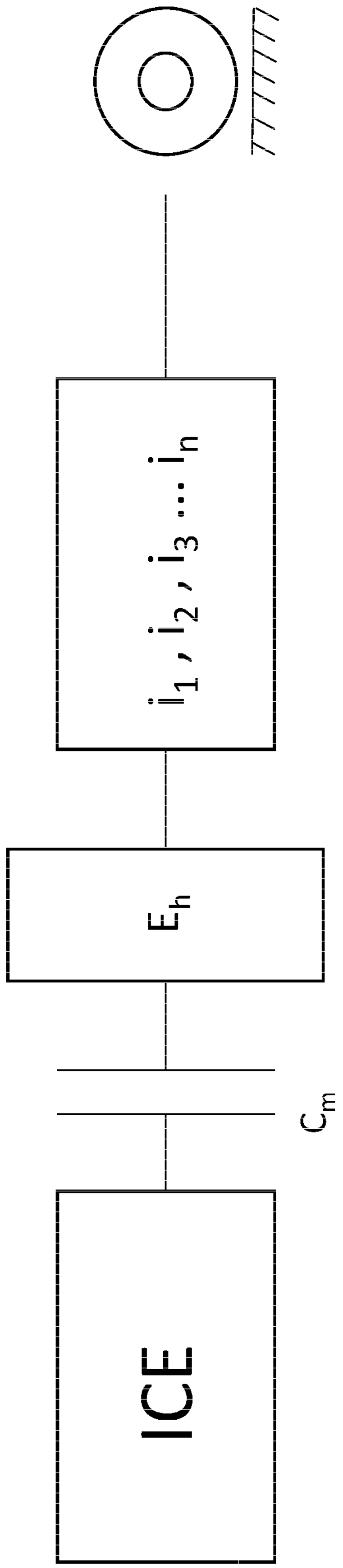


Fig. 3

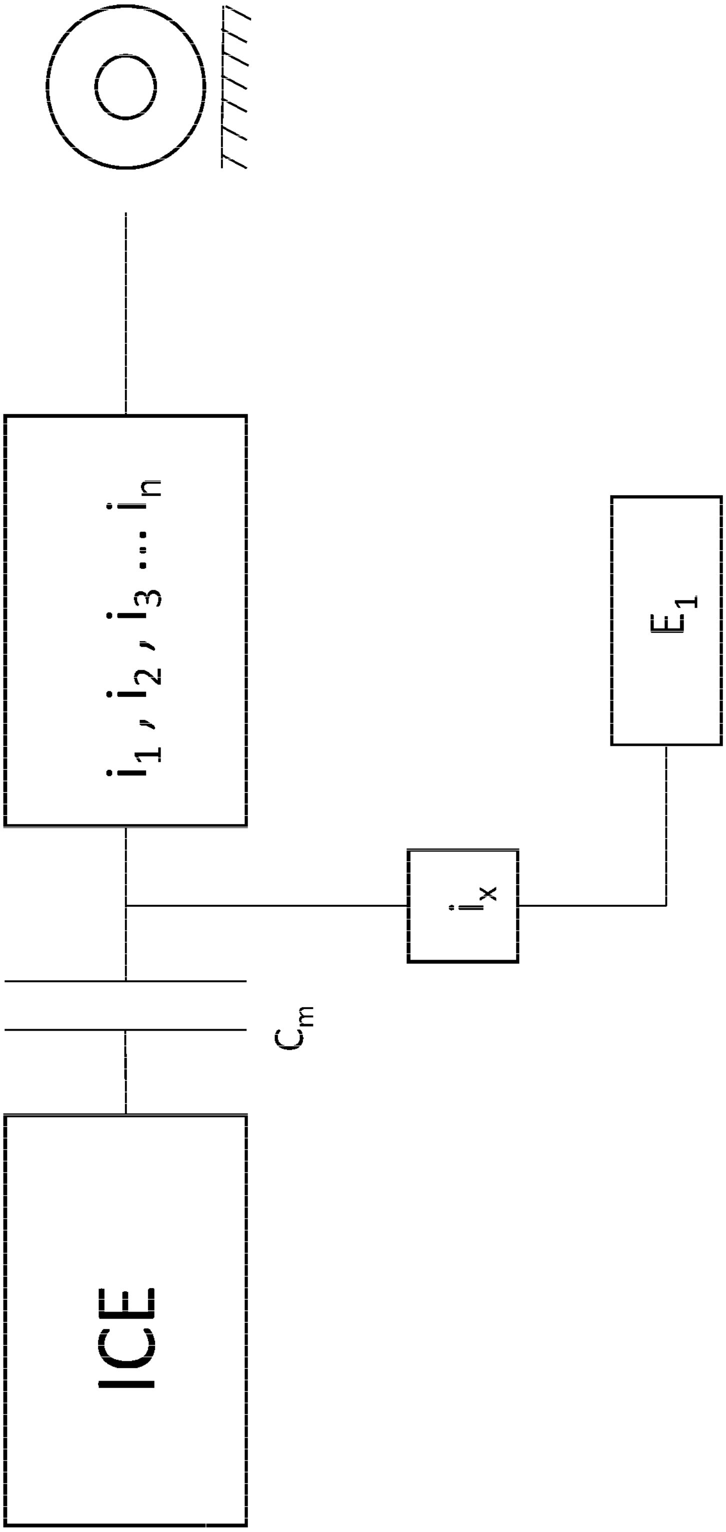


Fig. 4

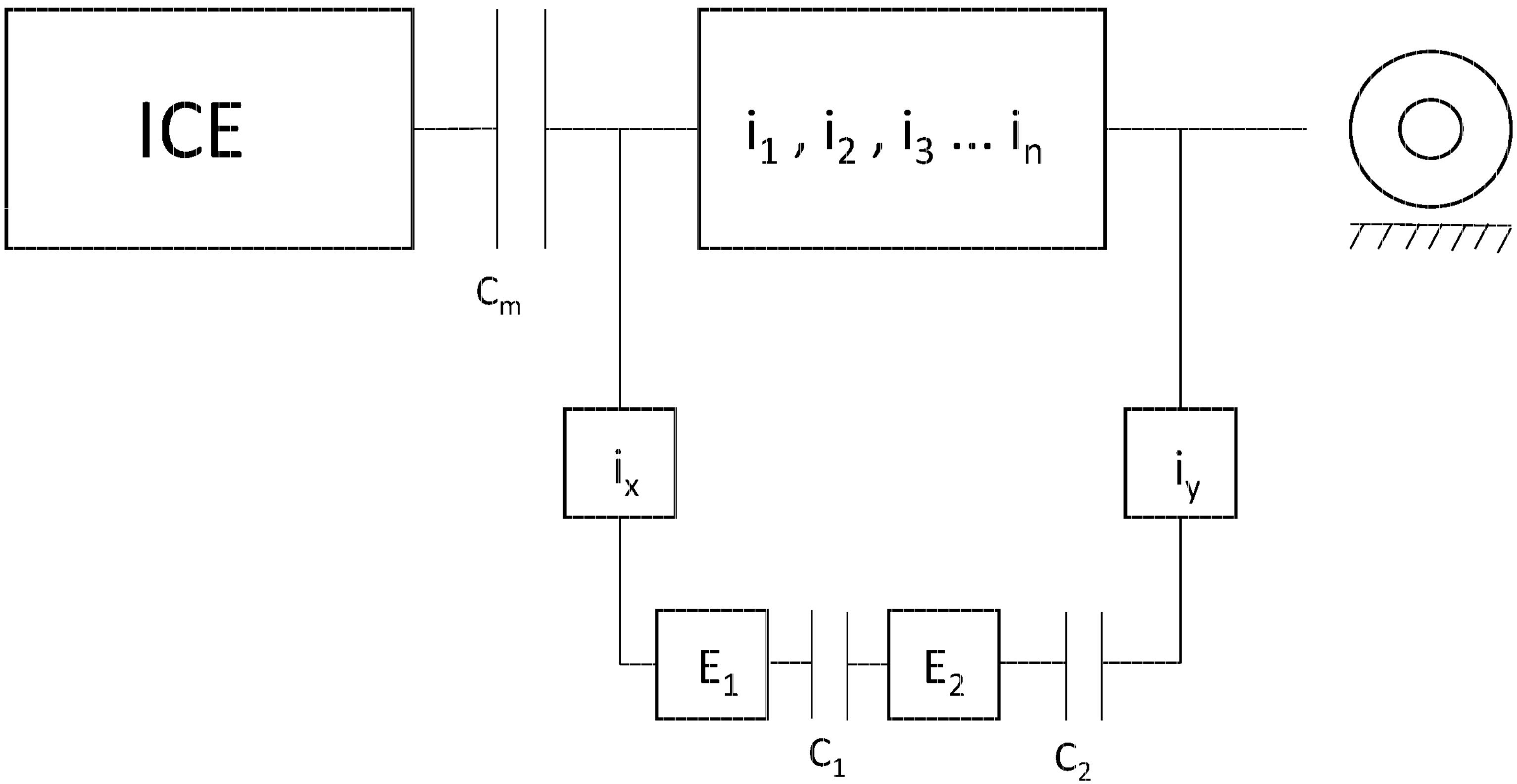


Fig. 5

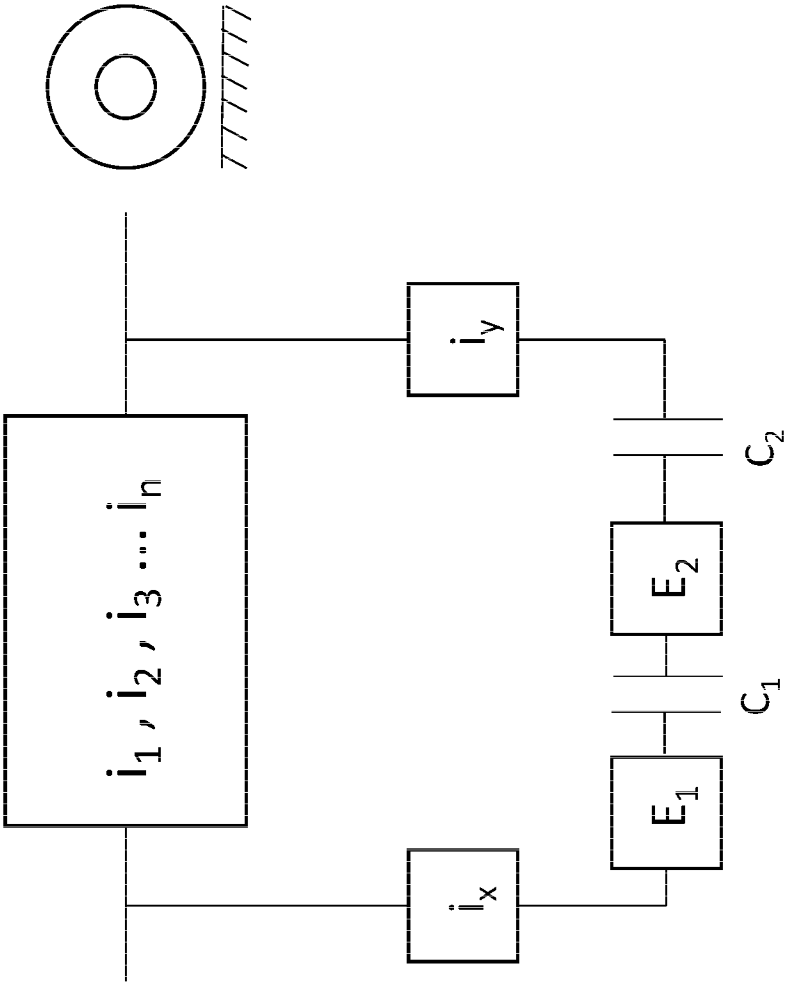


Fig. 6

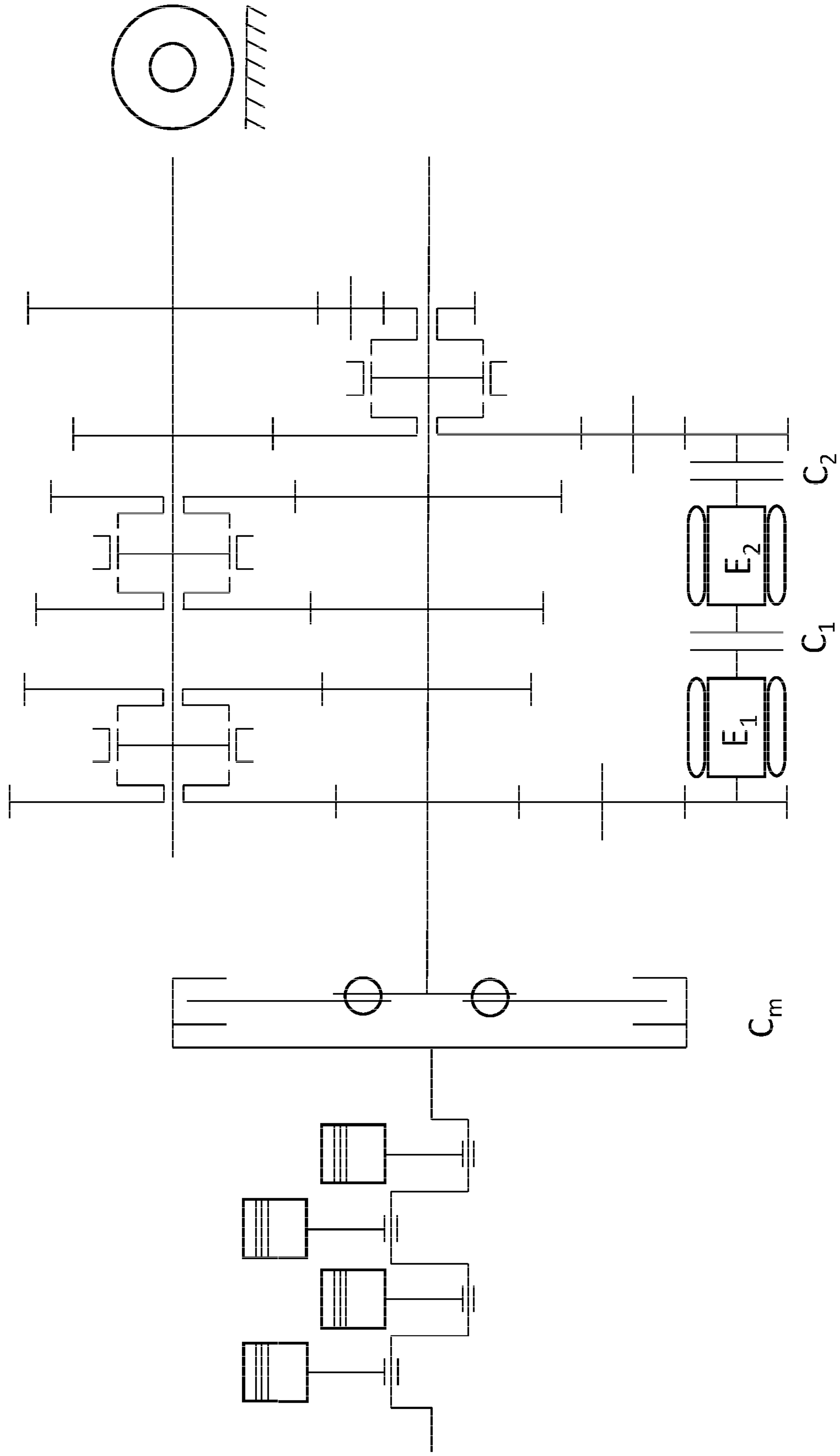


Fig. 7

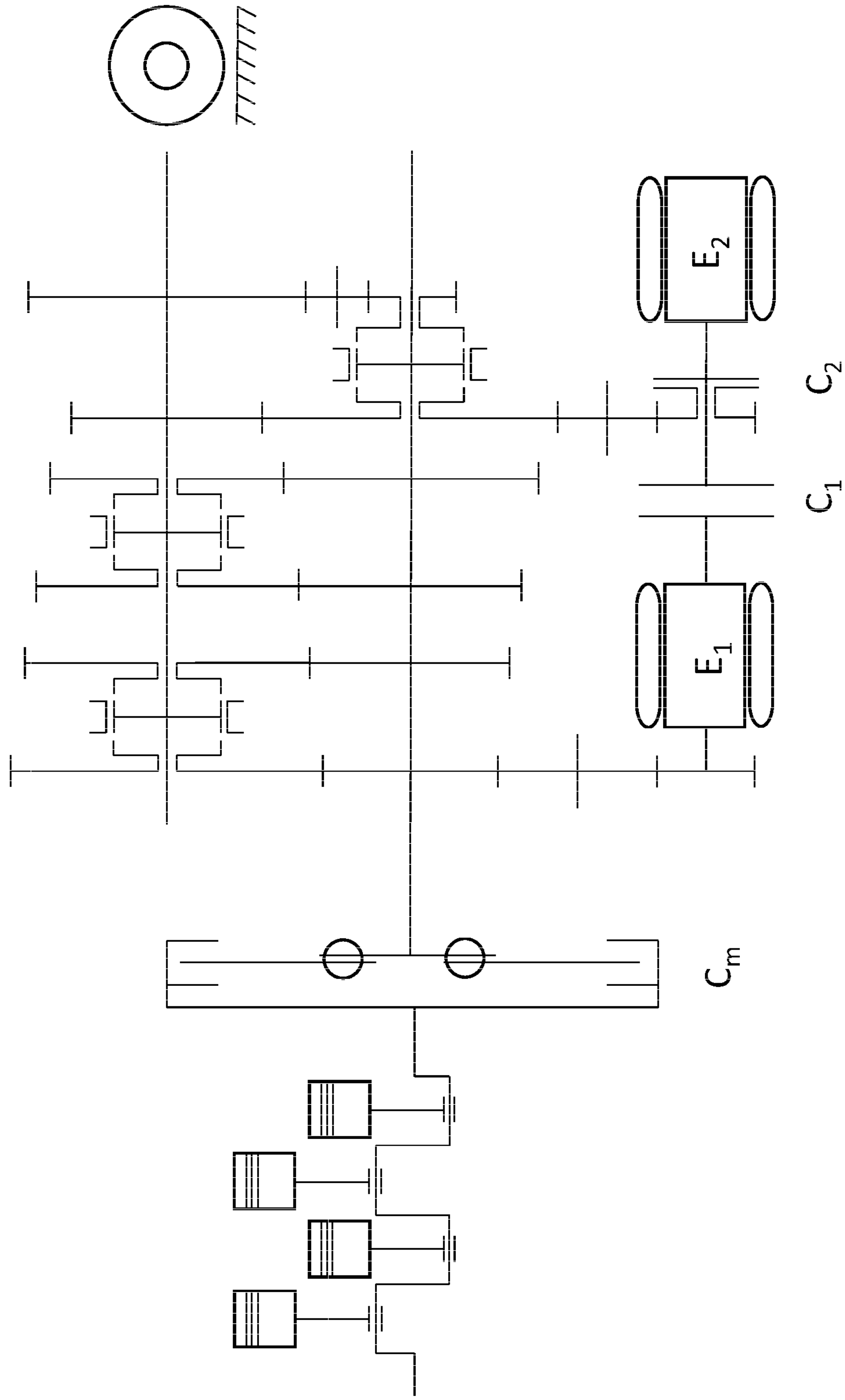


Fig. 8

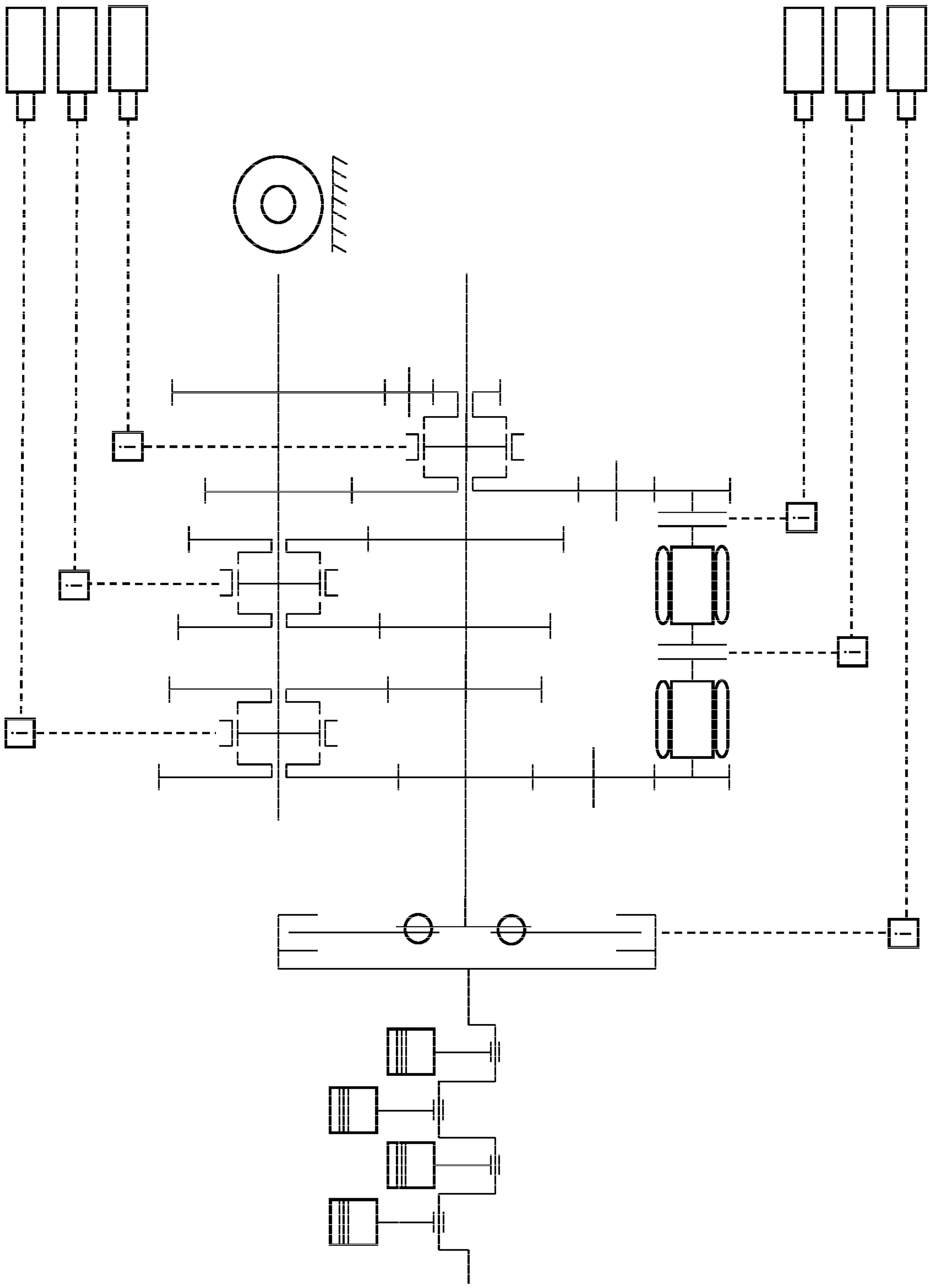


Fig. 9

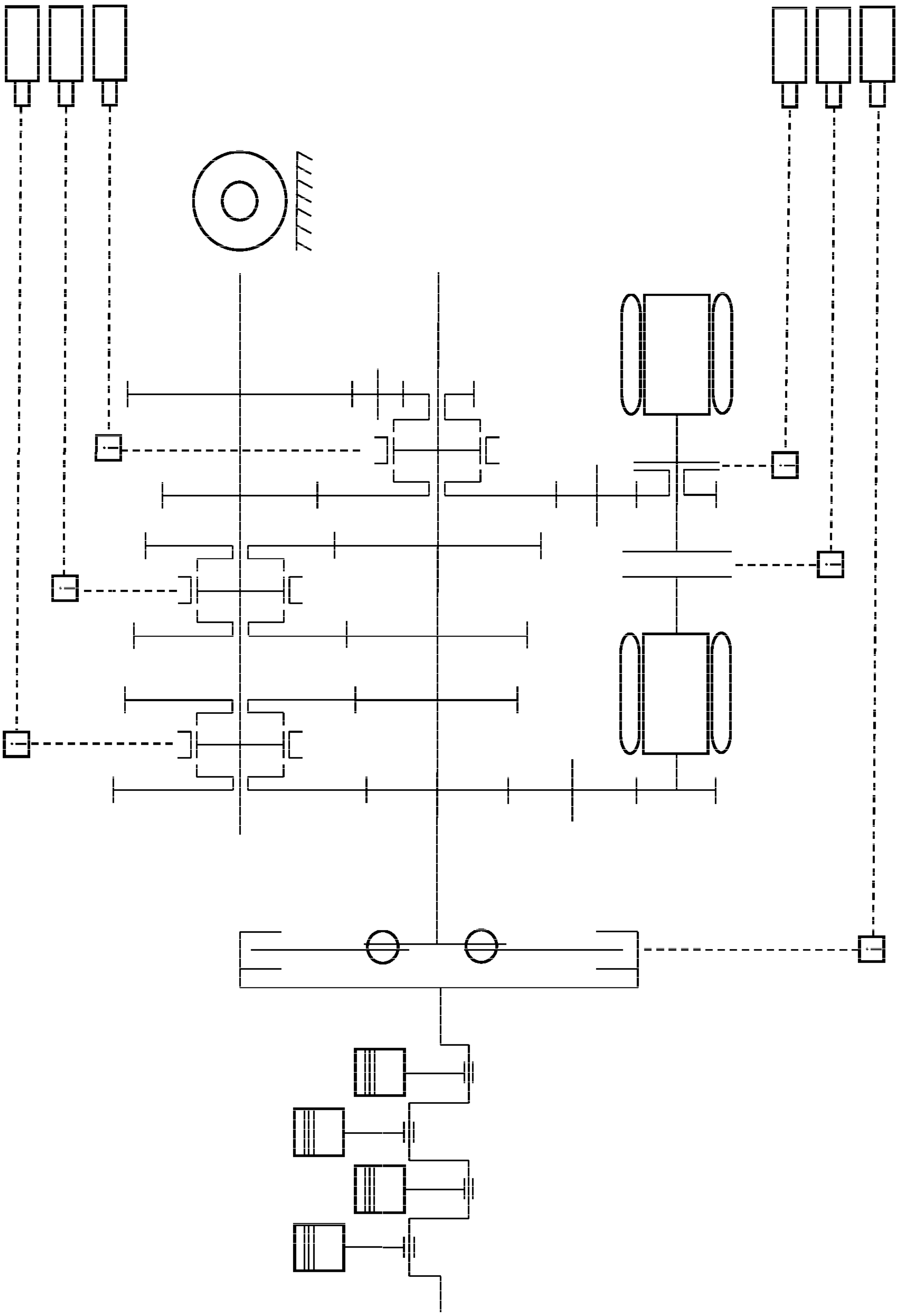


Fig. 10

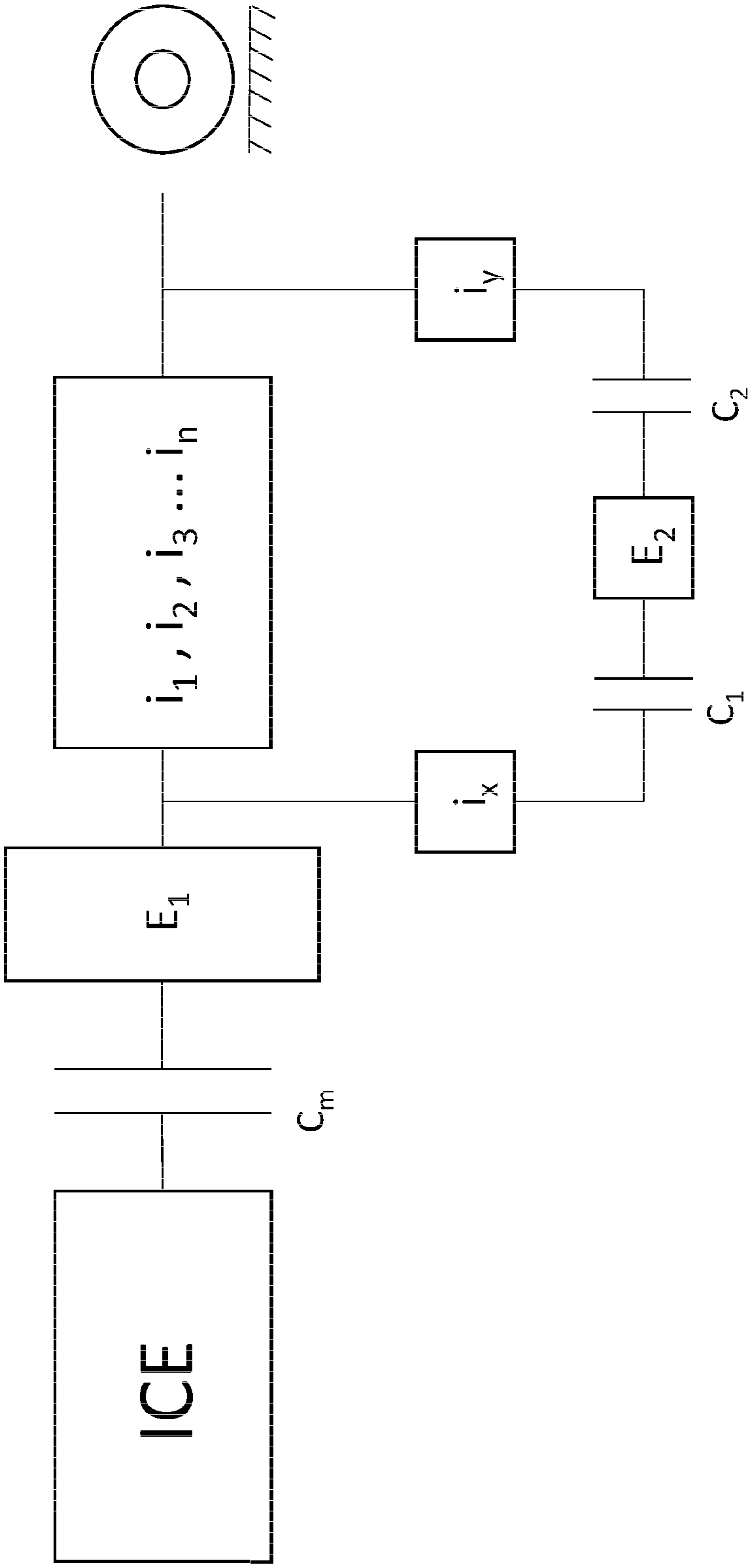


Fig. 11

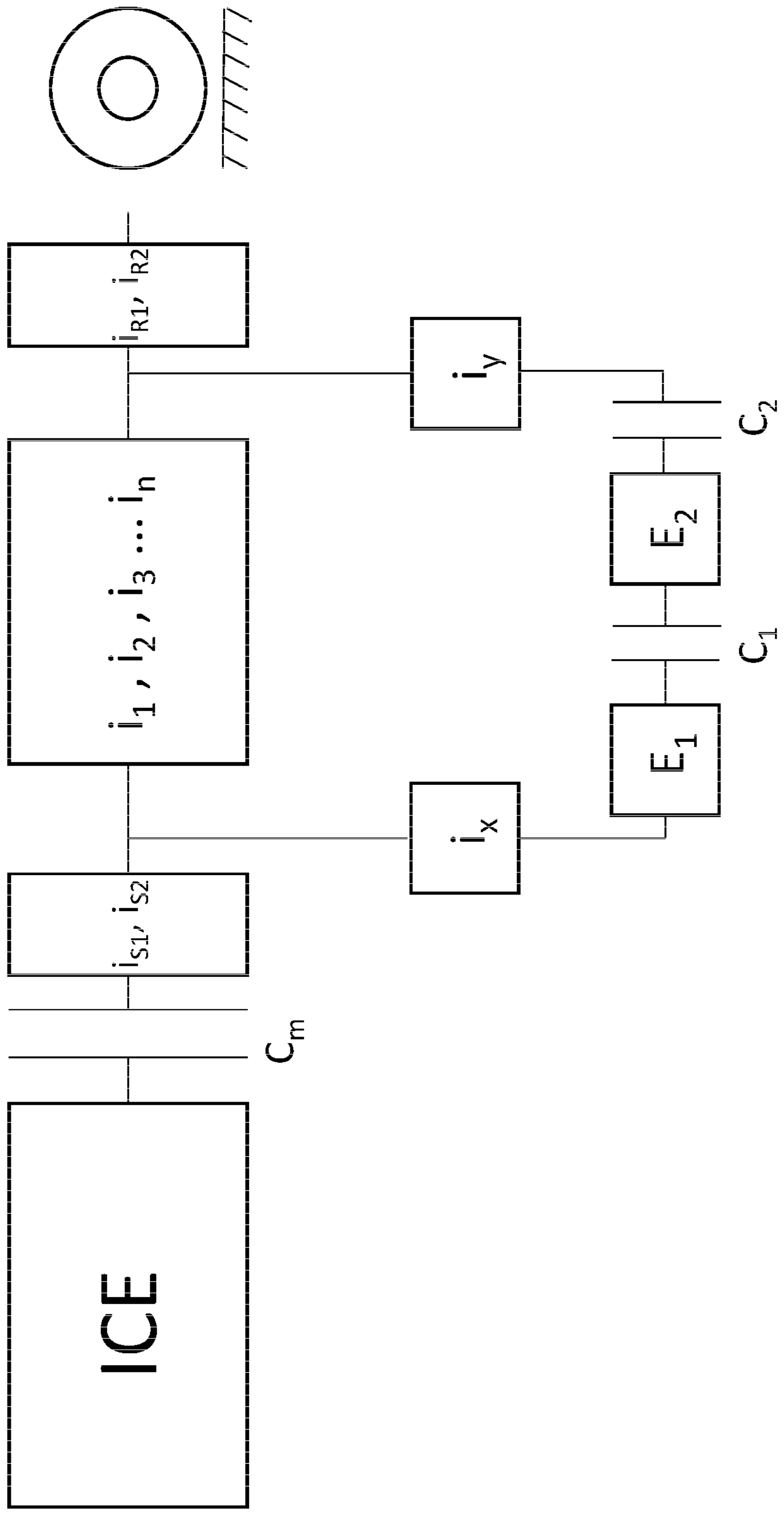


Fig. 12