



(51) International Patent Classification:

E02F 9/22 (2006.01) *B60W 10/06* (2006.01)
E02F 9/20 (2006.01)

(21) International Application Number:

PCT/EP2017/057968

(22) International Filing Date:

04 April 2017 (04.04.2017)

(25) Filing Language:

English

(26) Publication Language:

English

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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, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, 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, SA, 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, ST, SZ, TZ,

(54) Title: A METHOD FOR CONTROLLING A POWERTRAIN

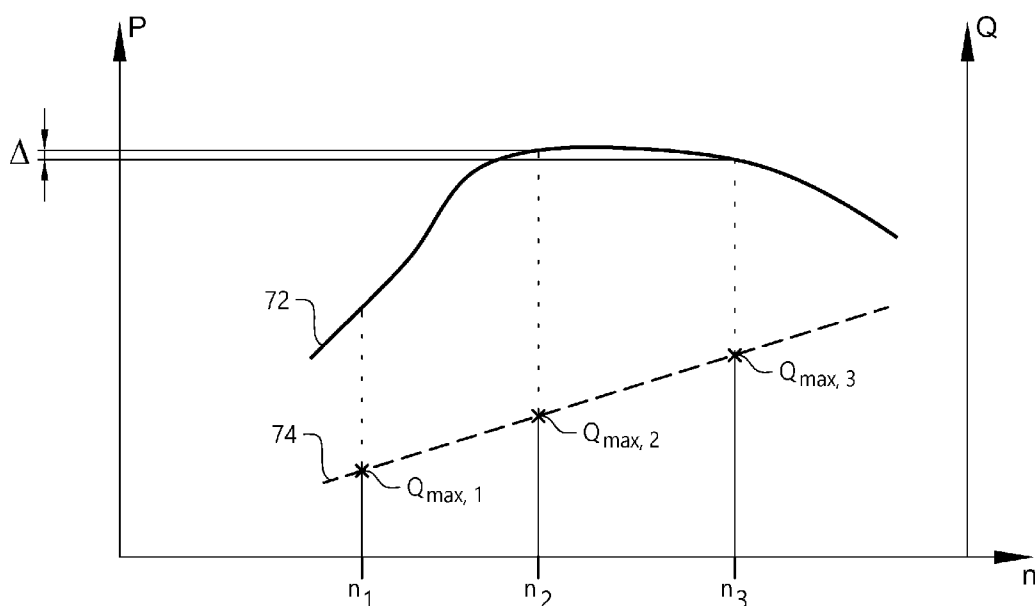


FIG. 4

(57) Abstract: The present invention relates to a method for controlling a powertrain (42) comprising an internal combustion engine (44) and a drivetrain (45), said powertrain (42) being adapted to produce drivetrain output power, said powertrain (42) further comprising a variable displacement hydraulic pump (62) operably connected to said internal combustion engine (44) and adapted to produce a hydraulic flow, said method comprising: - determining a drivetrain output power request; - determining a hydraulic flow request, and - on the basis of said drivetrain output power request and said hydraulic flow request, automatically controlling said internal combustion engine (44) such that the running internal combustion engine (44) operates at one of three predetermined engine speeds (n_1 ; n_2 ; n_3), wherein a first engine speed (n_1) is lower than a second engine speed (n_2) which in turn is lower than a third engine speed (n_3).

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, KM, ML, MR, NE, SN, TD, TG).

Published:

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

A method for controlling a powertrain

TECHNICAL FIELD

The invention relates to a method for controlling a powertrain. Moreover, the present invention relates to a control unit for controlling a powertrain. Further, the present
5 invention relates to a powertrain and/or a vehicle

The invention can in particular be applied in heavy-duty vehicles, such as trucks, buses and construction equipment. Although the invention will be described with respect to a wheel loader, the invention is not restricted to this particular vehicle, but may also be used
10 in other vehicles such as an articulated hauler or an excavator.

BACKGROUND

A powertrain comprising an internal combustion engine and a drivetrain may be adapted
15 to produce a drivetrain output power, realized as rotational torque for a certain rotational speed. Purely by way of example, a drivetrain for a vehicle, such as a working machine, may be adapted to produce traction power in order to propel the vehicle by applying a traction force at a certain rotational speed.

20 Moreover, the powertrain may further comprise a variable displacement hydraulic pump operably connected to the internal combustion engine and adapted to produce a hydraulic power, realized as a hydraulic flow with a certain hydraulic pressure.

For instance, a variable displacement hydraulic pump of a working machine powertrain
25 may be adapted to produce a hydraulic flow for steering the working machine and/or for operating an implement thereof.

The drivetrain output power and the hydraulic flow required at a certain time instant may require a specific power production by the internal combustion engine. As such, the
30 internal combustion engine should preferably be controlled such that its produced power meets or exceeds the power being required for meeting the drivetrain output power and the hydraulic flow required. However, in order to meet changes in the required drivetrain output power and/or the required hydraulic flow, the operating condition of the internal

combustion engine may change significantly and rapidly. Such changes may have an influence on the fuel economy as well as the working life of the powertrain.

SUMMARY

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An object of the invention is to provide a method for controlling a powertrain comprising an internal combustion engine and a drivetrain, wherein the internal combustion engine is operated in an appropriate manner whilst still being able to produce power sufficient for meeting a drivetrain output power request as well as a hydraulic flow request.

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The object is achieved by a method according to claim 1.

As such, the present invention relates to a method for controlling a powertrain comprising an internal combustion engine and a drivetrain. The powertrain is adapted to produce
15 drivetrain output power. The powertrain further comprises a variable displacement hydraulic pump operably connected to the internal combustion engine and adapted to produce a hydraulic flow.

The method comprises:

- 20
- determining a drivetrain output power request;
 - determining a hydraulic flow request, and
 - on the basis of the drivetrain output power request and the hydraulic flow request, automatically controlling the internal combustion engine such that the running
25 internal combustion engine operates at one of three predetermined engine speeds, wherein a first engine speed is lower than a second engine speed which in turn is lower than a third engine speed.

As used herein, the expression “drivetrain power” is intended to mean power being realized by the drivetrain as rotational torque at a certain rotational speed. Consequently,
30 the expression “drivetrain output power request” is intended to mean a request for a certain drivetrain power obtained accordingly.

Thus, the method of the present invention proposes that the running internal combustion engine selectively operates at one of three predetermined engine speeds. This implies an appropriate fuel economy and/or appropriate operating conditions for the internal combustion engine since the internal combustion engine may be such that it has
5 appropriate operating characteristics at the three predetermined engine speeds.

Moreover, the sound of the engine may be perceived by the operator of the vehicle and the operator may be able to discern which one of the three discrete engine speeds that the internal combustion engine is operated at. As such, operating the internal combustion
10 engine at one of the three predetermined speeds may provide appropriate feedback to the operator, for instance audio feed back from the sound of the engine indicative of a current load situation of the powertrain.

Optionally, of the first, second and third engine speeds, an available engine output power
15 from the internal combustion engine is lowest for the first engine speed.

Optionally, an absolute difference between the available engine output power for the second engine speed and the available engine output power for the third engine speed is less than 5% of the available engine output power for the second engine speed.
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Having the difference between the output power for the second and the third engine speeds within the above range may enable configurations of the internal combustion engine for more efficient fuel combustions, leading to reduced fuel consumption and exhaust emissions of the engine.

25 Optionally, the method comprises controlling the internal combustion engine such that the engine speed thereof assumes the lowest of the first, second and third engine speeds, by which speed it is possible to meet the drivetrain output power request as well as the hydraulic flow request.

30 Generally, the lowest engine speed is associated with the lowest fuel consumption. Thus, a control towards the lowest engine speed implies a lowered fuel consumption.

Optionally, the method comprises, upon detection that the hydraulic flow request implies a
35 hydraulic flow exceeding the hydraulic flow obtainable when the internal combustion is

running at the first engine speed, controlling the internal combustion engine such that the engine speed thereof assumes the third engine speed.

Going from the first engine speed directly to the third engine speed may be beneficial
5 under certain circumstances. For instance, if the hydraulic flow request implies a high hydraulic flow (e.g. a hydraulic flow close to a maximum hydraulic flow obtainable), going directly from the first engine speed to the third engine speed may increase an operator's impression of the machine's responsiveness. Moreover, going directly from the first engine speed to the third engine speed may reduce the number of engine speed change
10 occurrences which in turn implies advantageous energy efficiency.

In a similar vein, the method may optionally comprise changing the engine speed from the third engine speed directly down to the first engine speed.

15 Optionally, the method comprises controlling the internal combustion engine such that the engine speed is switched from a preceding engine speed to a different subsequent engine speed. The method further comprises:

- detecting a pump displacement change for said variable displacement hydraulic pump during the preceding engine speed and determining a first hydraulic flow
20 rate change on the basis of said pump displacement change and said preceding engine speed, and
- directly or indirectly controlling the displacement of the variable displacement hydraulic pump such that, when and while the engine speed changes to the subsequent engine speed, the variable displacement hydraulic pump produces a
25 hydraulic flow rate change corresponding to the first hydraulic flow rate change.

The above features imply a smooth change from one engine speed to another of the three engine speeds. Moreover, the above features imply that a flow rate change is maintained during the engine speed change.

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Optionally, the method comprises controlling the internal combustion engine such that the engine speed is switched from a preceding engine speed to a different subsequent engine speed, the method further comprises:

- determining a first hydraulic flow from the variable displacement hydraulic pump when the internal combustion engine is running at the preceding engine speed, and
- directly or indirectly controlling the displacement of the variable displacement hydraulic pump such that, when and while the engine speed changes to the subsequent engine speed, the variable displacement hydraulic pump produces a hydraulic flow corresponding to the first hydraulic flow.

The above features imply a smooth change from one engine speed to another of the three engine speeds. Moreover, the above features imply that a hydraulic flow rate is maintained during the engine speed change.

Optionally, the preceding engine speed is the third engine speed and the subsequent engine speed is the second engine speed.

Optionally, the preceding engine speed is the first engine speed and the subsequent engine speed is the second engine speed.

Optionally, the preceding engine speed is the second engine speed and the subsequent engine speed is the first engine speed.

Optionally, the powertrain is a vehicle powertrain and the drivetrain output power is used as traction power. The drivetrain output power request is a traction power request.

As an example, traction power may be realized as traction force at a certain vehicle speed.

Optionally, the powertrain comprises an electric machine connected in series with the internal combustion engine. As such, the powertrain may be a hybrid powertrain featuring an electric series hybrid drivetrain.

Optionally, the feature of determining a drivetrain output power request comprises predicting a future drivetrain output power requirement during a predetermined future time range. Such a prediction may further improve the operability of the powertrain since the

prediction implies that engine speed changes need not necessarily be executed on a highly frequent basis.

Optionally, the feature of predicting a future drivetrain output power requirement during a
5 predetermined future time range comprises:

- determining that the powertrain is operated in a repeated work cycle;
- determining which portion of the repeated work cycle that the powertrain currently is operated in;
- predicting the future drivetrain output power requirement during the predetermined
10 future time range by determining a drivetrain output power requirement associated with the repeated work cycle from the start to the end of the future time range, and
- determining the drivetrain output power request using the future drivetrain output power requirement during the predetermined future time range.

15 The above feature of predicting a future drivetrain output power requirement implies that the future requirement may be determined with a relatively high degree of certainty.

Optionally, the feature of determining a hydraulic flow request comprises predicting a future hydraulic flow requirement during a predetermined future time range. Again, such a
20 prediction may further improve the operability of the powertrain since the prediction implies engine speed changes may be made on a less frequent basis.

Optionally, the feature of predicting a future hydraulic flow requirement during a predetermined time range comprises:

- 25 – determining that the powertrain is operated in an repeated work cycle;
- determining which portion of the repeated work cycle that the powertrain currently is operated in;
- predicting the future hydraulic flow requirement for the predetermined future time range by determining a future hydraulic flow requirement associated with the
30 repeated work cycle from the start to the end of the future time range, and
- determining the hydraulic flow request using the future hydraulic flow requirement for the predetermined future time range.

The above feature of predicting a future hydraulic flow requirement implies that the future
35 requirement may be determined with a relatively high degree of certainty.

Purely by way of example, the drivetrain output power requirement and/or the future hydraulic flow requirement may be determined at one or more discrete time instants within the future time range including the end of the future time range. As a non-limiting
5 example, the one or more time instants may be evenly distributed over the future time range. It is also envisaged that the maximum required drivetrain output power may be determined continuously over the future time range.

A second aspect of the present invention relates to a control unit for controlling a
10 powertrain. The powertrain comprises an internal combustion engine and a drivetrain. The powertrain is adapted to produce drivetrain output power. The powertrain further comprises a variable displacement hydraulic pump operably connected to the internal combustion engine and adapted to produce a hydraulic flow. The control unit is adapted to:

- 15 – determine a drivetrain output power request;
- determine a hydraulic flow request, and
- on the basis of the drivetrain output power request and the hydraulic flow request, issue an internal combustion engine control signal indicative of that the running internal combustion engine should assume one of three predetermined engine
20 speeds, wherein a first engine speed is lower than a second engine speed which in turn is lower than a third engine speed.

Optionally, the control unit is adapted to perform a method for controlling a powertrain according to the first aspect of the present invention.

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Optionally, the powertrain comprises an electric machine connected in series with the internal combustion engine. As such, the powertrain may be a hybrid powertrain featuring an electric series hybrid drivetrain.

30 A third aspect of the present invention relates to a powertrain comprising an internal combustion engine and a drivetrain. The powertrain is adapted to produce drivetrain output power. The powertrain further comprises a variable displacement hydraulic pump operably connected to the internal combustion engine and adapted to produce a hydraulic flow. The powertrain comprises a control unit according to the second aspect of the
35 present invention.

Optionally, the powertrain further comprises an electric machine connected in series with the internal combustion engine.

- 5 A fourth aspect of the present invention relates to a vehicle, preferably a working machine, comprising a control unit according to the second aspect of the present invention and/or a powertrain according to the third aspect of the present invention.

Further advantages and advantageous features of the invention are disclosed in the
10 following description and in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the appended drawings, below follows a more detailed description of
15 embodiments of the invention cited as examples.

In the drawings:

Fig. 1 is a side view of a wheel loader;

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Fig. 2 is a schematic view of a powertrain;

Fig. 3 is a schematic view of another powertrain;

- 25 Fig. 4 and 5 each show a graph illustrating the power producible by an internal combustion engine as a function of the engine speed;

Fig. 6 is a flow chart of a method according to the present invention;

- 30 Fig. 7 is a schematic top view illustrating a work cycle, and

Fig. 8 is a graph illustrating drivetrain output power and hydraulic flow required during the Fig. 7 work cycle.

35 DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

Fig. 1 illustrates a vehicle exemplified as a wheel loader 10. The body of the wheel loader 10 comprises a front body section 12 and a rear body section 14, which sections each has an axle 16, 18 for driving a pair of wheels 20, 22. The body sections 12, 14 are connected to each other in such a way that they can pivot in relation to each other around a vertical axis by means of two first actuators in the form of hydraulic cylinders 24, 26 arranged between the two body sections 12, 14. The hydraulic cylinders 24, 26 are thus arranged one on each side of a horizontal centreline of the wheel loader 10 in a vehicle traveling direction in order to turn the wheel loader 10. As an alternative to the hydraulic cylinders 24, 26, a hydraulic motor may be used (not shown).

The wheel loader 10 comprises equipment 28 for handling objects or material. The equipment 28 comprises a load-arm unit 30 and an implement 32, which in Fig. 1 is exemplified as a bucket, fitted on the load-arm unit 30. A first end of the load-arm unit 30 is pivotally connected to the front vehicle section 12. The implement 32 is pivotally connected to a second end of the load-arm unit 30.

The load-arm unit 30 can be raised and lowered relative to the front section 12 of the vehicle by means of two second actuators in the form of two hydraulic cylinders 34, 36, each one of which being connected at one end to the front vehicle section 12 and at the other end to the load-arm unit 30. The implement 32 can be tilted relative to the load-arm unit 30 by means of a third actuator in the form of a hydraulic cylinder 38, which is connected at one end to the front vehicle section 12 and at the other end to the implement 32 via a link-arm system 40.

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Fig. 2 illustrates an embodiment of a powertrain 42 according to the present invention. The powertrain comprises an internal combustion engine 44 and a drivetrain 45. Moreover, the powertrain 42 is adapted to produce drivetrain output power. In the Fig. 2 embodiment, which is a vehicle powertrain, the drivetrain output power is used as traction power. To this end, the drivetrain 45 comprises axles 16, 18 each one driving a pair of wheels 20, 22. Purely by way of example, the axles 16, 18 may be the axles presented hereinabove in relation to Fig. 1. However, it is also contemplated that the embodiments of the powertrain need not necessarily produce traction power for a vehicle. Instead, embodiments of the powertrain are contemplated which produce drivetrain output power for another purpose. As a non-limiting example, embodiments of the powertrain may be

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adapted to be located in a factory (not shown) and may be adapted to produce drivetrain output power intended to be used by one or more machines (not shown) in the factory.

Moreover, the Fig. 2 drivetrain 45 comprises a first electric machine 46, operably
5 connected to the internal combustion engine 44. In the Fig. 2 embodiment, the first electric machine 46 is mechanically connected to the internal combustion engine 44 by means of a first shaft 48.

Moreover, the Fig. 2 drivetrain 45 comprises a second electric machine 50 electrically
10 connected to the first electric machine 46. Purely by way of example, and as indicated in Fig. 2, the first and second electric machines 46, 50 are connected to one another via electric power conducting means 52 and form an electric drivetrain. Purely by way of example, such electric power conducting means 52 may comprise a cable (not shown).

Moreover, in the Fig. 2 embodiment, the first and second electric machines 46, 50 are
15 directly connected to one another. However, it is also envisaged that embodiments of the power train may comprise energy storage means (not shown), such as a battery, electrically connected to one or both of the electric machines 46, 50. In Fig. 2, the powertrain is a hybrid powertrain featuring an electric series hybrid drivetrain. Purely by way of example, each one of the first and second electric machines 46, 50 may be
20 adapted to function as an electric generator as well as an electric motor.

The second electric machine 50 is operatively connected to the axles 16, 18. In the Fig. 2 embodiment, the second electric machine 50 is mechanically connected to a transmission arrangement 54 which in turn is connected to the axles 16, 18 via a drive shaft assembly
25 56. In Fig. 2, such mechanical connection is obtained by virtue of a second shaft 58 mechanically connecting the second electric machine 50 to the transmission arrangement 54. Furthermore, as indicated in Fig. 2, the drive shaft assembly 56 comprises a third shaft 60 mechanically connected to the transmission arrangement 54.

30 The transmission arrangement 54 may for instance be adapted to provide a fixed gear ratio between the second shaft 58 and the third shaft 60. As another alternative, the transmission arrangement 54 may for instance be adapted to provide a variable gear ratio, e.g. continuously or in steps, between the second shaft 58 and the third shaft 60. Purely by way of example, the transmission arrangement 54 may comprise a gearbox (not
35 shown) and/or a torque converter (not shown).

Further, Fig. 2 illustrates that the powertrain 42 comprises a variable displacement hydraulic pump 62 operably connected to the internal combustion engine 44 and adapted to produce a hydraulic flow. In the Fig. 2 embodiment, there is only one such variable displacement pump, but it is easily conceivable to connect several such devices in order to increase the flow capacity and/or supply hydraulic flow to several hydraulic systems.

In the Fig. 2 embodiment, the variable displacement hydraulic pump 62 is mechanically connected to the internal combustion engine 44 via a power take off unit for instance. As such, though purely by way of example, the powertrain may provide a fixed relation between the engine speed of the internal combustion engine 44 and the rotational speed at which the variable displacement hydraulic pump 62 rotates. It is conceivable that said power take off includes a clutch that can mechanically disengage pump 62 from engine 44 (not shown in Fig. 2).

Purely by way of example, variable displacement hydraulic pump 62 may be adapted to supply fluid to an actuator set 63 comprising at least one actuator. As a non-limiting example, and as indicated in Fig. 2, the actuator set 63 may comprise one or more of the hydraulic cylinders 24, 26, 34, 36, 38 presented hereinabove with reference to the Fig. 1 working machine 10.

By virtue of the fact that the pump 62 has a variable displacement, a hydraulic flow provided by the pump 62 is dependent on the current displacement of the pump 62 as well as the current engine speed of the internal combustion engine 44. As indicated in Fig. 2, the powertrain 42 may comprise a pump actuator 64 adapted to control the displacement of the pump 62. Furthermore, as may be gleaned from Fig. 2, the powertrain 42 may comprise a control unit 66 for controlling the powertrain 42. Purely by way of example, and as implied in Fig. 2, the control unit 66 may be in communication with the internal combustion engine 44 as well as the pump actuator 64.

As a non-limiting example, and has been indicated hereinabove, the displacement of the pump 62 may be controlled by the pump actuator 64. However, it is also envisaged that the displacement may be controlled using other means. Purely by way of example, the displacement of the pump 62 may be controlled by reducing input signals from an operator or by limiting the pressure of a hydraulic signal to a displacement regulator (not shown) of the pump 62.

Moreover, as indicated in Fig. 2, the control unit 66 may be in communication with request input means 68. Purely by way of example, the request input means 68 may comprise actuating means such as a lever, a knob, a button, a touch screen (not shown) or the like.

5 As a non-limiting example, an operator may employ the request input means 68 in order to transmit a drivetrain output power request and/or a hydraulic flow request to the control unit 66.

Instead of, or in addition to, the request input means 68, the control unit 66 may be in
10 communication with a sensor assembly 70 comprising one or more sensors. As a non-limiting example, in embodiments of the powertrain 42 being associated with a vehicle 10, such as the Fig. 2 embodiment, the sensor assembly 70 may comprise a sensor adapted to determine the geographical position of the vehicle 10. As a non-limiting example, the sensor assembly 70 may comprise a global positioning system (not shown).

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It should be noted that other embodiments of the powertrain 42 are envisaged. To this end, reference is made to Fig. 3 illustrating a powertrain 42 comprising a drivetrain 45 in which each wheel 20, 22 is connected to an individual electric machine 50 via an individual transmission arrangement 54. Each one of the Fig. 3 individual electric machine
20 50 is connected to the first electric machine 46, e.g. via a common electric power conducting means 52 or individual electric power conducting means 52. It is also contemplated that embodiments of the powertrain 42 may comprise an individual electric machine 50 connected to each axle 16, 18 via an individual transmission arrangement 54.

25 Further embodiments of the powertrain 42 are envisaged. Purely by way of example, alternative embodiments of the powertrain need not necessarily comprise electric machines. As such, embodiments of the powertrain are contemplated in which hydraulic machines are utilized as well as embodiments in which the first shaft 48 in Fig. 2 is mechanically connected to the transmission arrangement 54.

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Fig. 4 presents a curve 72 for the available engine output power P producible by an internal combustion engine as a function of the engine speed. Purely by way of example, the internal combustion engine associated with the Fig. 4 graph may be the internal combustion engine illustrated in Fig. 2.

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Moreover, as indicated in Fig. 4, the internal combustion engine is associated with three predetermined engine speeds, wherein a first engine speed n_1 is lower than a second engine speed n_2 which in turn is lower than a third engine speed n_3 . Purely by way of example, and as indicated in Fig. 4, of the first, second and third engine speeds n_1 , n_2 , n_3 ,
 5 an available engine output power P from said internal combustion engine is lowest for the first engine speed n_1 .

Moreover, as another non-limiting example, an absolute difference between the available engine output power for the second engine speed n_2 and the available engine output
 10 power for the third engine speed n_3 is less than 5%, alternatively less than 2%, of the available engine output power for the second engine speed n_2 . Put differently, the available engine output power for the second engine speed n_2 is comparable to the available engine output power for the third engine speed n_3 .

15 In the Fig. 4 example, the available engine output power for the second engine speed n_2 is greater than the available engine output power for the third engine speed n_3 . However, it is also envisaged that the available engine output power for the third engine speed n_3 is greater than the available engine output power for the second engine speed n_2 . To this end, reference is made to Fig. 5, illustrating such a scenario.

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Each one of Fig. 4 and 5 further presents a curve 74 showing that the available hydraulic flow Q from the variable displacement hydraulic pump 62 operably connected to the internal combustion engine is dependent on the engine speed when the displacement of said pump is constant (i.e. fixed). As can be seen from each one of Fig. 4 and Fig. 5, for a
 25 maximum displacement of the variable displacement hydraulic pump, the maximum available hydraulic flow increases with increasing engine speed. As such, and as may be gleaned from each one of Fig. 4 and 5, the maximum available hydraulic flow for the third engine speed n_3 is greater than the maximum available hydraulic flow for the second engine speed n_2 which in turn is greater than the maximum available hydraulic flow for the
 30 first engine speed n_1 .

Put differently, for the first engine speed n_1 , the hydraulic flow fed from the variable displacement hydraulic pump can be varied from a minimum flow to a first maximum flow $Q_{\max,1}$. The range of flows obtainable at the first engine speed n_1 is indicated by the solid
 35 line extending from zero flow to $Q_{\max,1}$ in Fig. 4. However, it is also envisaged that in

implementations of the variable displacement hydraulic pump, the range of flows obtainable at the first engine speed n_1 may extend from a non-zero minimum flow to the first maximum flow $Q_{\max,1}$. Irrespective of the end points of the range of flows associated with the first engine speed n_1 , by controlling the displacement of the variable displacement hydraulic pump, a flow within the range may be produced by the variable displacement hydraulic pump 62.

In a similar vein, for the second engine speed n_2 , the hydraulic flow fed from the variable displacement hydraulic pump can be varied from a minimum flow, e.g. a zero flow, to a second maximum flow $Q_{\max,2}$. The second maximum flow $Q_{\max,2}$ is greater than the first maximum flow $Q_{\max,1}$. For the third engine speed n_3 , the hydraulic flow fed from the variable displacement hydraulic pump can be varied from a minimum flow, e.g. a zero flow, to a third maximum flow $Q_{\max,3}$. The third maximum flow $Q_{\max,3}$ is greater than the second maximum flow $Q_{\max,2}$.

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Fig. 6 illustrates a flow chart of a method according to the present invention. Purely by way of example, the method may be carried out by a control unit 66 communicating with each one of the internal combustion engine 44 and the variable displacement hydraulic pump 62. The method is for controlling a powertrain 42 comprising an internal combustion engine 44 and a drivetrain 45. Moreover, and as intimated hereinabove, the powertrain 42 is adapted to produce drivetrain output power. The powertrain 42 further comprises a variable displacement hydraulic pump 62 operably connected to the internal combustion engine 44 and adapted to produce a hydraulic flow. The method according to the present invention comprises:

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- S10 determining a drivetrain output power request;
- S12 determining a hydraulic flow request, and
- S14 on the basis of the drivetrain output power request and the hydraulic flow request, automatically controlling the internal combustion engine such that the running internal combustion engine operates at one of three predetermined engine speeds n_1 , n_2 , n_3 , wherein a first engine speed n_1 is lower than a second engine speed n_2 , which in turn is lower than a third engine speed n_3 .

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As a non-limiting example, the feature S14 may be implemented such that the internal combustion engine is controlled such that the running internal combustion engine always operates at one of three predetermined engine speeds n_1 , n_2 , n_3 .

- 5 The feature S10 of determining a drivetrain output power request and the feature S12 of determining a hydraulic flow request presented in sequence in the Fig. 6. However, it should be noted that embodiments of the method are contemplated in which the features S10, S12 are performed simultaneously and/or in which the feature S12 is carried out before feature S10.

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Irrespective of in which order the features S10, S12 are carried out, the features S10, S12 may for instance comprise determining a current drivetrain output power request and/or a current hydraulic flow request. As a non-limiting example, a current drivetrain output power request and/or a current hydraulic flow request may be determined by

- 15 receiving information from an operator, for instance via the request input means 68 presented hereinabove in relation to Fig. 2.

As another non-limiting example, and as will be elaborated on hereinbelow, the features S10, S12 may for instance comprise predicting a future drivetrain output power

- 20 requirement and/or a future hydraulic flow requirement during a predetermined future time range. As a non-limiting example, a future drivetrain output power requirement and/or a future hydraulic flow requirement may be determined by a control unit 66, for instance using information received from a sensor assembly 70 in communication with the control unit 66, see e.g. Fig. 2.

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As a non-limiting example, the engine speed may be controlled by controlling the fluid supply to the internal combustion engine 44.

Purely by way of example, the method may comprise controlling the internal combustion engine 44 such that the engine speed thereof assumes the lowest of the first, second and third engine speeds n_1 , n_2 , n_3 , by which it is possible to meet the drivetrain output power request as well as the hydraulic flow request.

- 30 It is also contemplated that the method need not necessarily control the engine speed such that the engine speed is changed to an adjacent engine speed. For instance, it is

envisaged that the embodiments of the method may comprise, upon detection that the hydraulic flow request implies a hydraulic flow exceeds the hydraulic flow obtainable when the internal combustion is running at the first engine speed n_1 , controlling the internal combustion engine such that the engine speed thereof assumes the third engine speed

5 n_3 .

Purely by way of example, in an operating condition in which the internal combustion engine 44 is runs at the second engine speed n_2 and the hydraulic pump displacement is maximum, the only possibility is to further increase the pump speed. Thus, in case of
10 insufficient flow at the second engine speed n_2 , a transition to the third engine speed n_3 is needed, which may take time to conclude and thereafter execute.

In a condition in which the internal combustion engine 44 runs at the first engine speed n_1 and a hydraulic flow request is determined which corresponds to a hydraulic flow which
15 cannot be achieved when the internal combustion engine 44 runs at the second engine speed n_2 , it may be beneficial to perform a transition directly from the first engine speed n_1 to the third engine speed n_3 and to control the pump displacement such that the current flow request is fulfilled at the third engine speed n_3 .

20 If a hydraulic flow request indicative of a further increase in hydraulic flow is thereafter determined, the pump displacement may be increased further. On the other hand, if a hydraulic flow request indicative of a hydraulic flow decrease is thereafter determined, it may be beneficial to change the engine speed to the second engine speed n_2 .

25 When changing the engine speed from a preceding engine speed to a different subsequent engine speed, the displacement of the variable displacement hydraulic pump 62 may also be controlled in order to obtain a smooth change in the flow produced by the pump 62 during the transition between the engine speeds.

30 Purely by way of example, the displacement of the variable displacement hydraulic pump 62 may be controlled such that a hydraulic flow rate change (i.e. a decrease or an increase Q' in the flow fed by the pump 62) present when the internal combustion engine is operated at the preceding engine speed is substantially maintained when the engine speed has been changed to the subsequent engine speed. For instance, if the variable
35 displacement hydraulic pump 62 is controlled so as to have a certain pump displacement

change for a preceding engine speed and the engine speed is changed to a subsequent engine speed whilst the certain pump displacement change is maintained, a significant alteration of the hydraulic flow rate change may occur which may be undesired since such an alteration may affect the behaviour of components fed by the hydraulic flow. For

5 instance, if an operator intends to perform an operation requiring a constant hydraulic flow rate change, such as raising the implement 32 at a relatively constant acceleration, it may be desired if the hydraulic flow rate change remains relatively constant even when the engine speed is changed. Any significant alteration of the hydraulic flow rate change may results in undesired jerks in the implement 32.

10

As such, though purely by way of example, an embodiment of the method may comprise:

– Detecting a pump displacement change for the variable displacement hydraulic pump 62 during the preceding engine speed and determining a first hydraulic flow rate change Q'_1 on the basis of the pump displacement change and the preceding engine speed. Thus, the method embodiment may comprise detecting that a first hydraulic flow rate change is requested by an operator and the method embodiment may also comprise determining that the flow rate change should be maintained as the engine speed changes. Purely by way of example, an operator may request that that the flow rate change should be maintained over engine speed changes. As a non-limiting example, such a request may be entered as a general powertrain setting or alternatively as a setting associated with a specific operation of the powertrain.

– Moreover, the method embodiment further comprises directly or indirectly controlling the displacement of the variable displacement hydraulic pump 62 such that, when and while the engine speed changes to the subsequent engine speed, the variable displacement hydraulic pump produces a hydraulic flow rate change corresponding to the first hydraulic flow rate change Q'_1 . As such, the flow rate change, which may be needed in order to perform a desired operation, is maintained as the engine speed changes.

As another non-limiting example, the displacement of the variable displacement hydraulic pump 62 may be controlled such that a hydraulic flow present when the internal combustion engine is operated at the preceding engine speed is substantially maintained when the engine speed has been changed to the subsequent engine speed.

As such, though purely by way of example, the method may comprise:

- Determining a first hydraulic flow Q_1 from the variable displacement hydraulic pump 62 when the internal combustion engine 44 is running at the preceding engine speed. As a non-limiting example, the first hydraulic flow Q_1 may be determined on the basis of a detected current pump displacement and the preceding engine speed. As another non-limiting example, the first hydraulic flow Q_1 may be determined using a flow meter (not shown).
- Moreover, the method embodiment further comprises directly or indirectly controlling the displacement of the variable displacement hydraulic pump 62 such that, when and while the engine speed changes to the subsequent engine speed, the variable displacement hydraulic pump 62 produces a hydraulic flow corresponding to the first hydraulic flow Q_1 .

15

As a non-limiting example, the preceding engine speed is the third engine speed n_3 and the subsequent engine speed is the second engine speed n_2 . As another non-limiting example, the preceding engine speed is the first engine speed n_1 and the subsequent engine speed is the second engine speed n_2 . As a further non-limiting example, the preceding engine speed is the second engine speed n_2 and the subsequent engine speed is the first engine speed n_1 .

As has been intimated hereinabove, the drivetrain output power request and/or the hydraulic flow request may be a current drivetrain output power request and/or a current hydraulic flow request. However, embodiments of the present method are contemplated in which the feature of determining a drivetrain output power request and/or the hydraulic flow request comprises predicting a future drivetrain output power requirement and/or a future hydraulic flow requirement during a predetermined future time range.

An example involving the above embodiments for determining the drivetrain output power request as well as the hydraulic flow request is presented hereinbelow with reference to Fig. 7 and Fig. 8.

With reference to FIG. 7, a work cycle in the form of so-called short-cycle loading for a wheel loader 10, such as the wheel loader illustrated in Fig. 1, is shown. The short-cycle

loading is characterized in that the longest distance that the vehicle travels between a loading and an unloading position does not exceed a certain number of metres, for example in the order of 20 metres (depending on the workplace and the wheel loader size). More specifically, the wheel loader 10 is in Fig. 7 used to scoop up material from a loading position (excavating a natural ground 76) with the implement 32 – which
5 loading position (excavating a natural ground 76) with the implement 32 – which implement in Fig. 7 is exemplified as a bucket - and unload it in the unloading position (onto a container of a dump truck 78 in the form of an articulated hauler).

FIG. 7 shows a driving pattern comprising a series of steps from excavation to loading
10 onto the dump truck 78. Moreover, Fig. 8 illustrates the required drivetrain output power P_R as well as the required hydraulic flow Q_R during each one of the Fig. 7 steps.

According to the Fig. 7 driving pattern, the wheel loader 10 travels forward in a first step, indicated by arrow 80, to the natural ground 76. In embodiments of the wheel loader 10
15 comprising a transmission arrangement with discrete gears, the wheel loader 10 may as a non-limiting example be operated in a forward second speed gear during the first step. However, it is also envisaged that the Fig. 7 driving pattern can be performed by a wheel loader 10 comprising a stepless transmission arrangement. The wheel loader is in a straight position, wherein the front and rear vehicle parts are in line. With reference to Fig.
20 8, the first step 80 is associated with a relatively low required drivetrain output power as well as a relatively low required hydraulic flow.

When the wheel loader 10 approaches the natural ground 76, in a second step, it thrusts into the natural ground in for example a forward first speed gear in order to increase
25 tractive force, see arrow 82. The lifting arm unit 30 is raised, wherein the bucket 30 is filled with material from the natural ground. As may be gleaned from Fig. 8, the second step is consequently associated with relatively a relatively large required drivetrain output power as well as a relatively large required hydraulic flow.

30 When the excavation is finished, the wheel loader 10 is in a third step retreated from the excavating operation position at a high speed in for example a reverse second speed gear, see arrow 84, which may require a relatively large required drivetrain output power. The wheel loader is thereafter turned to the right (or to the left) in a fourth step, see arrow 86 which turning operation may require a required hydraulic flow increase.

The wheel loader 10 then moves forward in a fifth step, see arrow 88, while turning hard to the left (or right), then straightens out the vehicle to travel to approach the dump truck 78 at a high speed (indicating an increase in required drivetrain output power) in a sixth step, see arrow 90. The lifting arm unit 30 is raised, thus requiring a relatively large
5 required hydraulic flow, the bucket 32 tilted and the material is deposited in the load receiver 78. When a loading operation of the dump truck 78 is finished, the wheel loader 10 moves away in reverse from the dump truck 78 at a high speed in a seventh step, see arrow 92, turns to a stop position and is driven forwards again, see arrow 94, towards the natural ground 76 in a first step of a new work cycle round. As such, in Fig. 8, the steps 80
10 and 94 coincide.

As may be realized from Fig. 8, each one of the steps is associated with a specific required drivetrain output power as well as a specific required hydraulic flow. As such, if it is determined that the powertrain 42, forming part of the Fig. 7 wheel loader 10, is
15 operated in the repeated Fig. 7 work cycle, it may be determined in which portion of the repeated work cycle that the powertrain 42 currently is operated. In Fig. 8, at a starting time T_0 , the powertrain 42 is in the third step, indicated by reference numeral 84.

Purely by way of example, the determination that that the powertrain 42 is operated in a
20 repeated work cycle may be based on a conclusion that the required drivetrain output power levels and/or the required hydraulic flow levels are repeated on a regular basis. In other words, upon detection of recurrent required drivetrain output power levels and/or required hydraulic flow levels, it may be determined that the powertrain 42 is operated in repeated work cycle. Instead of, or in addition to, basing the repeated work cycle
25 determination on the required levels, if the powertrain is a vehicle powertrain, a determination that the powertrain 42 is operated in a repeated work cycle may be based on a conclusion that the vehicle is travelling along a recurrent travel path.

Moreover, though purely by way of example, the determination of which portion of the
30 repeated work cycle that the powertrain 42 currently is operated in may be determined by comparing the present required drivetrain output power and/or the present required hydraulic flow to the required levels detected for the work cycle to thereby determine which portion of the repeated work cycle having required levels corresponding to the present required drivetrain output power and/or the present required hydraulic flow.
35 Instead of, or in addition to, basing the portion determination on the required levels, if the

powertrain is a vehicle powertrain, the determination of which portion of the repeated work cycle that the powertrain 42 currently is operated in may be based on a determination of the current position of the vehicle and comparing that position to the positions along the recurrent travel path of the work cycle.

5

For a future time range ΔT , starting at T_0 – which is located in the third step 84 - and ending at T_1 - which is located in the fifth step 88 - the future drivetrain output power requirement as well as the future hydraulic flow requirement may be predicted. The future requirements may for instance be determined from the start T_0 to the end T_1 of the future time range ΔT . As a non-limiting example, the future drivetrain output power requirement may be set to correspond to the maximum required drivetrain output power during the future time range ΔT . In a similar vein, the future hydraulic flow requirement may be set to correspond to the maximum required hydraulic flow during the future time range ΔT . Purely by way of example, the maximum required drivetrain output power may be determined for one or more discrete time instants within the future time range ΔT including the end T_1 of the future time range ΔT . As a non-limiting example, the one or more discrete time instants may be evenly distributed over the future time range ΔT . It is also envisaged that the maximum required drivetrain output power may be determined continuously over the future time range ΔT .

20

Once the future drivetrain output power requirement and the future hydraulic flow requirement have been determined, the drivetrain output power request may be set using the future drivetrain output power requirement (for instance by setting the drivetrain output power request equal to the future drivetrain output power requirement) and the hydraulic flow request may be set using the future hydraulic flow requirement (for instance by setting the hydraulic flow request equal to the future hydraulic flow requirement). The actual hydraulic flow fed by the variable displacement hydraulic pump 62 throughout the future time range ΔT may then be controlled by controlling the pump's displacement. Thus, though purely by way of example, the future hydraulic flow requirement may be indicative of the maximum flow required during the future time range ΔT and the internal combustion engine may be controlled so as to assume the engine speed n_1 , n_2 , n_3 for which the maximum required flow, in combination with the drivetrain output power request, can be met.

30

Although the above example with reference to Fig. 7 and Fig. 8 determines the drivetrain output power request as well as the hydraulic flow request by predicting future requirements, it is also envisaged that embodiments of the present method may determine only one of the requests by predicting future requirements and for example
5 determining the other request using input from an operator.

Irrespective of how the requests are determined, the requests may be used for controlling a powertrain according to the method of the present invention, viz by controlling the internal combustion engine so as to assume one of the three engine speeds n_1 , n_2 , n_3 .

10

It is to be understood that the present invention is not limited to the embodiments described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the appended claims.

15

CLAIMS

1. A method for controlling a powertrain (42) comprising an internal combustion engine (44) and a drivetrain (45), said powertrain (42) being adapted to produce drivetrain output power, said powertrain (42) further comprising a variable displacement hydraulic pump (62) operably connected to said internal combustion engine (44) and adapted to produce a hydraulic flow, said method comprising:
- determining a drivetrain output power request;
 - determining a hydraulic flow request, and
 - on the basis of said drivetrain output power request and said hydraulic flow request, automatically controlling said internal combustion engine (44) such that the running internal combustion engine (44) operates at one of three predetermined engine speeds (n_1 , n_2 , n_3), wherein a first engine speed (n_1) is lower than a second engine speed (n_2) which in turn is lower than a third engine speed (n_3).
2. The method according to claim 1, wherein, of the first, second and third engine speeds (n_1 , n_2 , n_3), an available engine output power from said internal combustion engine (44) is lowest for the first engine speed (n_1).
3. The method according to claim 1 or claim 2, wherein an absolute difference between the available engine output power for the second engine speed (n_2) and the available engine output power for the third engine speed (n_3) is less than 5% of the available engine output power for the second engine speed (n_2).
4. The method according to any one of claims 1 to 3, wherein said method comprises:
- controlling said internal combustion engine (44) such that the engine speed thereof assumes the lowest of said first, second and third engine speeds (n_1 , n_2 , n_3), by which it is possible to meet the drivetrain output power request as well as the hydraulic flow request.
5. The method according to any one of claims 1 to 4, wherein said method comprises:
- upon detection that said hydraulic flow request implies a hydraulic flow exceeding the hydraulic flow obtainable when the internal combustion is running at the first

engine speed (n_1), controlling said internal combustion engine (44) such that the engine speed thereof assumes said third engine speed (n_3).

6. The method according to any one of the preceding claims, wherein said method
5 comprises controlling said internal combustion engine (44) such that said engine speed is switched from a preceding engine speed to a different subsequent engine speed, said method further comprises:

- detecting a pump displacement change for said variable displacement hydraulic pump (62) during the preceding engine speed and determining a first hydraulic
10 flow rate change (Q'_1) on the basis of said pump displacement change and said preceding engine speed, and
- directly or indirectly controlling the displacement of said variable displacement hydraulic pump (62) such that, when and while said engine speed changes to said subsequent engine speed, said variable displacement hydraulic pump (62)
15 produces a hydraulic flow rate change corresponding to said first hydraulic flow rate change (Q'_1).

7. The method according to any one of claims 1 - 5, wherein said method comprises controlling said internal combustion engine (44) such that said engine speed is switched
20 from a preceding engine speed to a different subsequent engine speed, said method further comprises:

- determining a first hydraulic flow (Q_1) from said variable displacement hydraulic pump (62) when said internal combustion engine (44) is running at said preceding engine speed, and
- 25 – directly or indirectly controlling the displacement of said variable displacement hydraulic pump (62) such that, when and while said engine speed changes to said subsequent engine speed, the variable displacement hydraulic pump (62) produces a hydraulic flow corresponding to said first hydraulic flow (Q_1).

30 8. The method according to claim 6 or claim 7, wherein said preceding engine speed (n_3) is said third engine speed and said subsequent engine speed is said second engine speed (n_2).

9. The method according to any one of the preceding claims, wherein said powertrain (42) is a vehicle powertrain and the drivetrain output power is used as traction power, said drivetrain output power request being a traction power request.

5 10. The method according to any one of the preceding claims, wherein said powertrain (42) further comprises an electric machine (46, 50) connected in series with said internal combustion engine (44).

11. The method according to any one of the preceding claims, wherein said feature of
10 determining a drivetrain output power request comprises predicting a future drivetrain output power requirement during a predetermined future time range.

12. The method according to claim 11, wherein said feature of predicting a future drivetrain output power requirement during a predetermined future time range comprises:

- 15 – determining that said powertrain (42) is operated in a repeated work cycle;
 – determining which portion of the repeated work cycle that the powertrain (42) currently is operated in;
 – predicting said future drivetrain output power requirement during said predetermined future time range by determining a drivetrain output power
20 requirement associated with said repeated work cycle from the start to the end of said future time range, and
 – determining said drivetrain output power request using said future drivetrain output power requirement during said predetermined future time range.

25 13. The method according to any one of the preceding claims, wherein said feature of determining a hydraulic flow request comprises predicting a future hydraulic flow requirement during a predetermined future time range.

14. The method according to claim 13, wherein said feature of predicting a future
30 hydraulic flow requirement during a predetermined time range comprises:

- determining that said powertrain (42) is operated in an repeated work cycle;
 – determining which portion of the repeated work cycle that the powertrain (42) currently is operated in;

- predicting said future hydraulic flow requirement for said predetermined future time range by determining a future hydraulic flow requirement associated with said repeated work cycle from the start to the end of said future time range, and
- determining said hydraulic flow request using said future hydraulic flow requirement for said predetermined future time range.

15. A control unit (66) for controlling a powertrain (42), said powertrain (42) comprising an internal combustion engine (44) and a drivetrain (45), said powertrain (42) being adapted to produce drivetrain output power, said powertrain (42) further comprising a variable displacement hydraulic pump (62) operably connected to said internal combustion engine (44) and adapted to produce a hydraulic flow, said control unit being adapted to:

- determine a drivetrain output power request;
- determine a hydraulic flow request, and
- on the basis of said drivetrain output power request and said hydraulic flow request, issue an internal combustion engine (44) control signal indicative of that the running internal combustion engine (44) should assume one of three predetermined engine speeds, wherein a first engine speed is lower than a second engine speed which in turn is lower than a third engine speed.

16. The control unit (66) according to claim 15, wherein said control unit is adapted to perform a method for controlling a powertrain (42) according to any one of claims 1 – 14.

17. A powertrain (42) comprising an internal combustion engine (44) and a drivetrain (45), said powertrain (42) being adapted to produce drivetrain output power, said powertrain (42) further comprising a variable displacement hydraulic pump (62) operably connected to said internal combustion engine (44) and adapted to produce a hydraulic flow, said powertrain (42) comprising a control unit according to claim 14 or claim 15.

18. The powertrain (42) according to claim 17, wherein said powertrain (42) further comprises an electric machine (46, 50) connected in series with said internal combustion engine (44).

19. A vehicle, preferably a working machine, comprising a control unit according to any one of claims 15 - 16 and/or a powertrain (42) according to any one of claims 17 - 18.

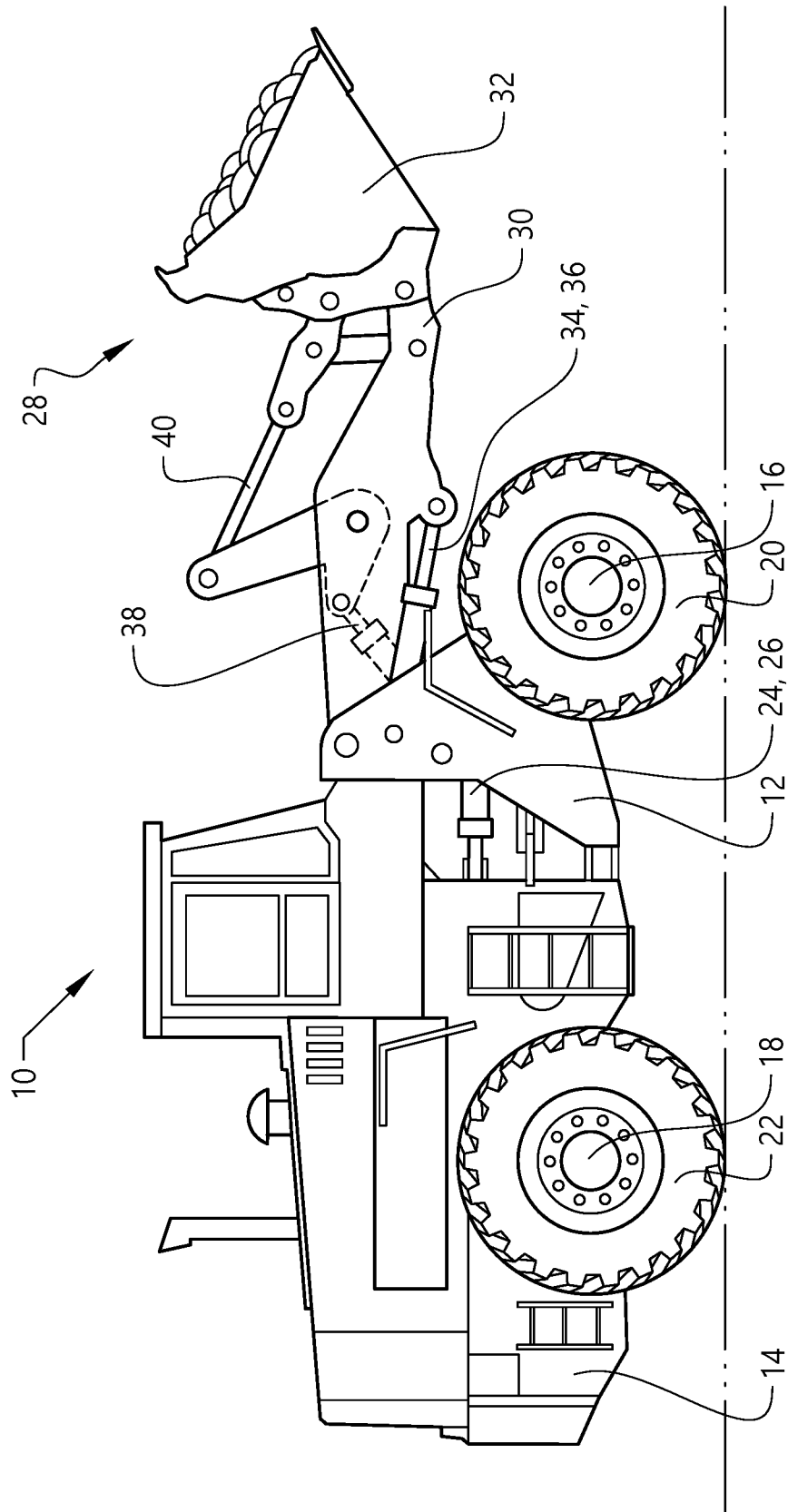


FIG. 1

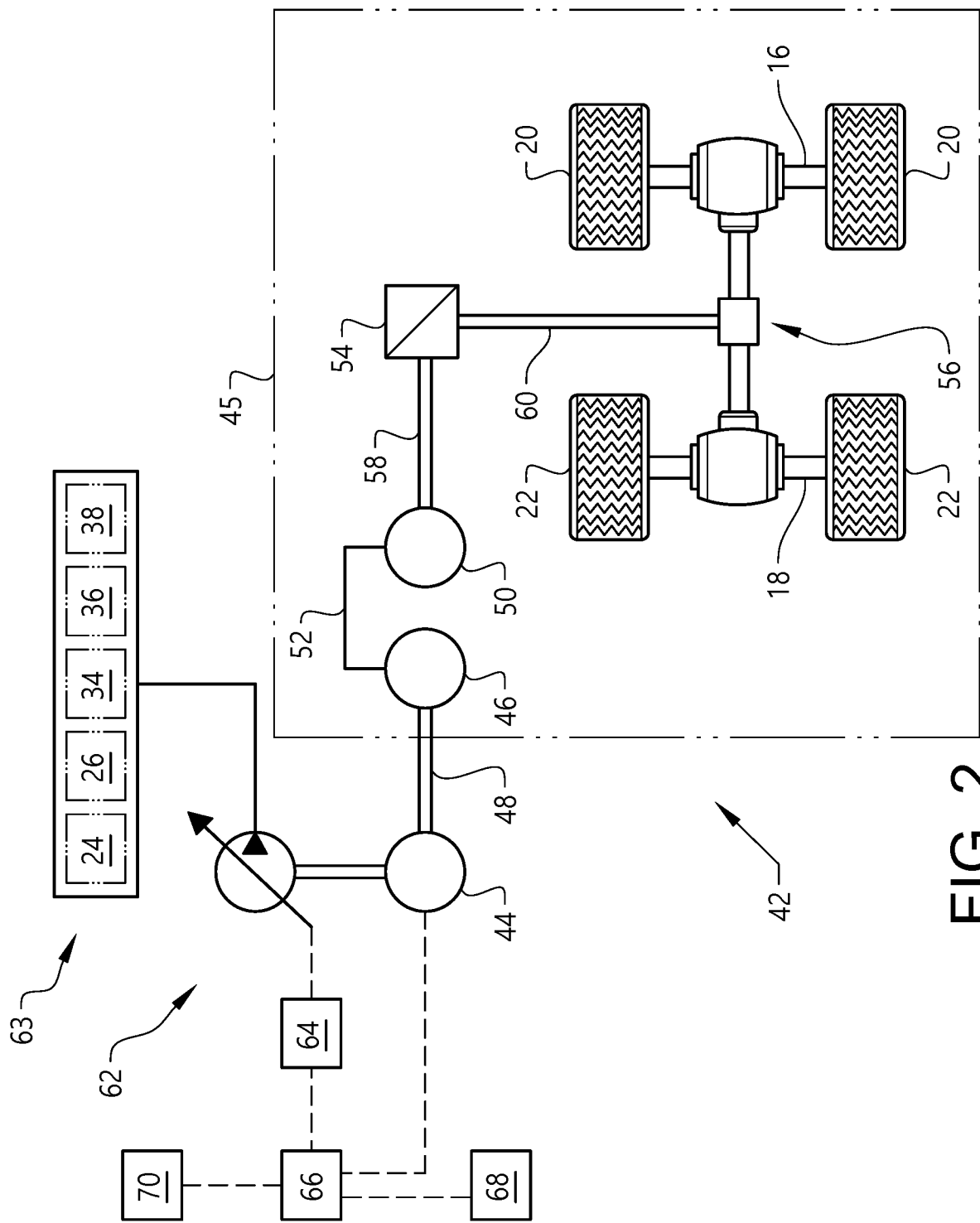


FIG. 2

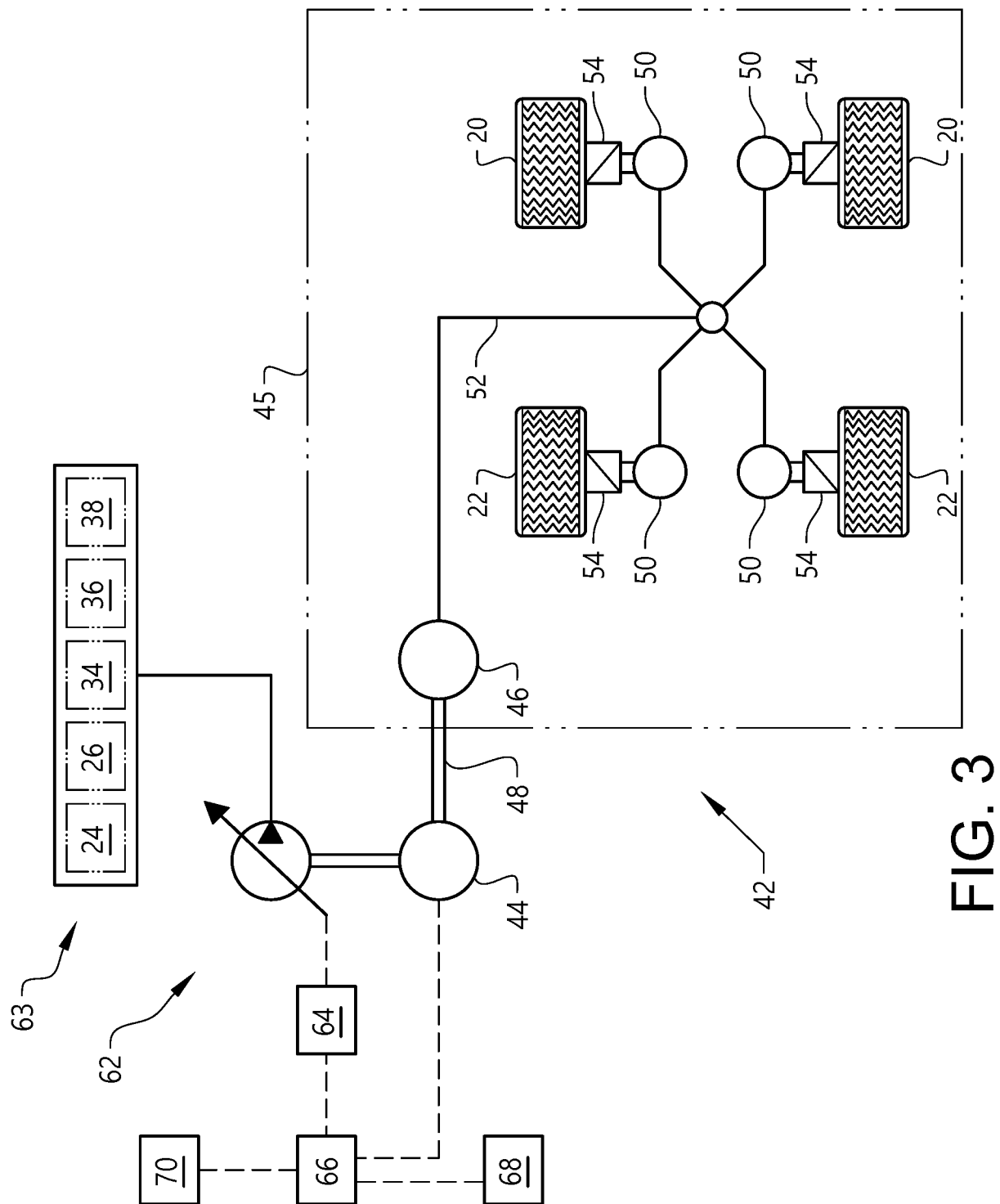


FIG. 3

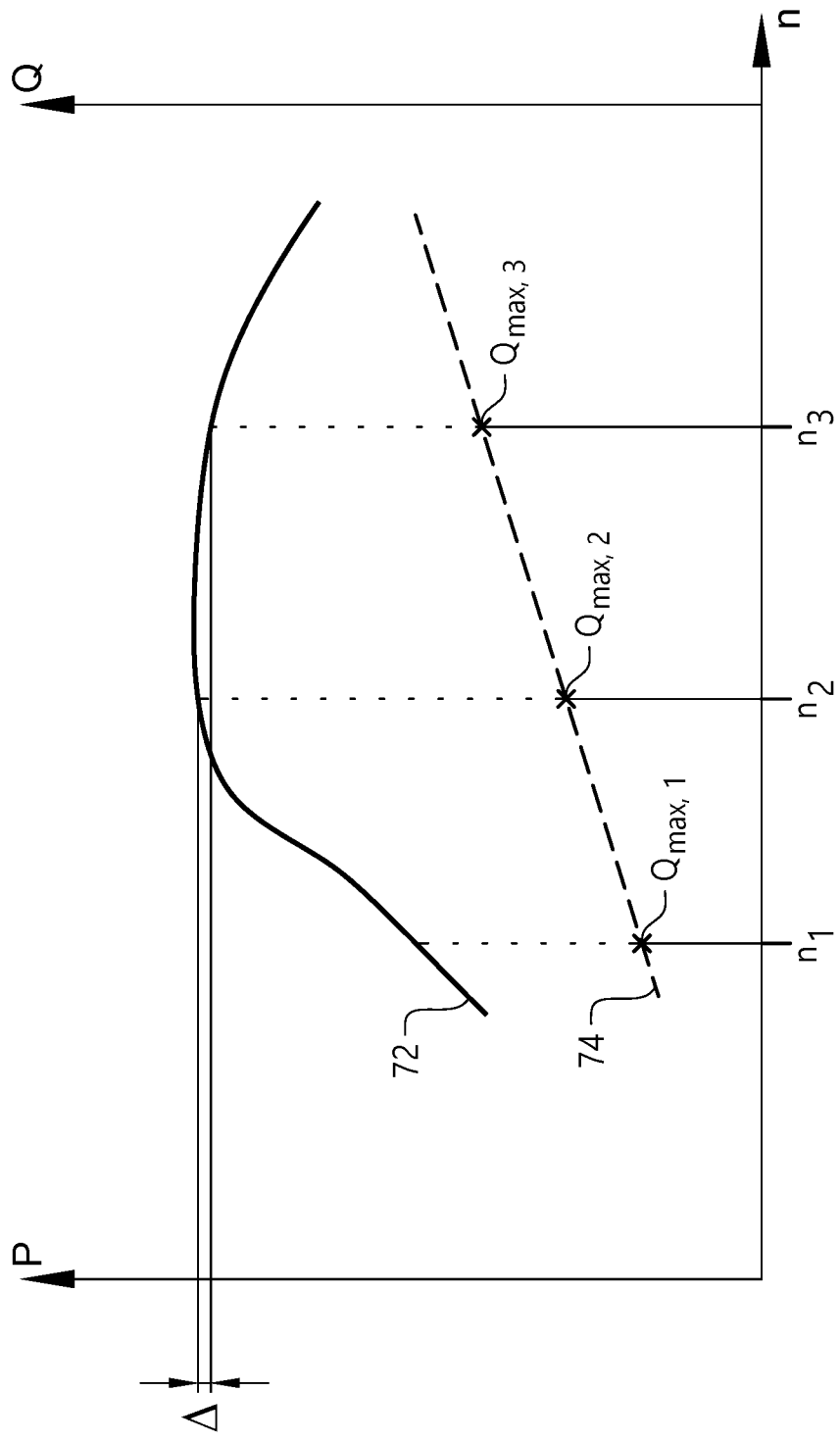


FIG. 4

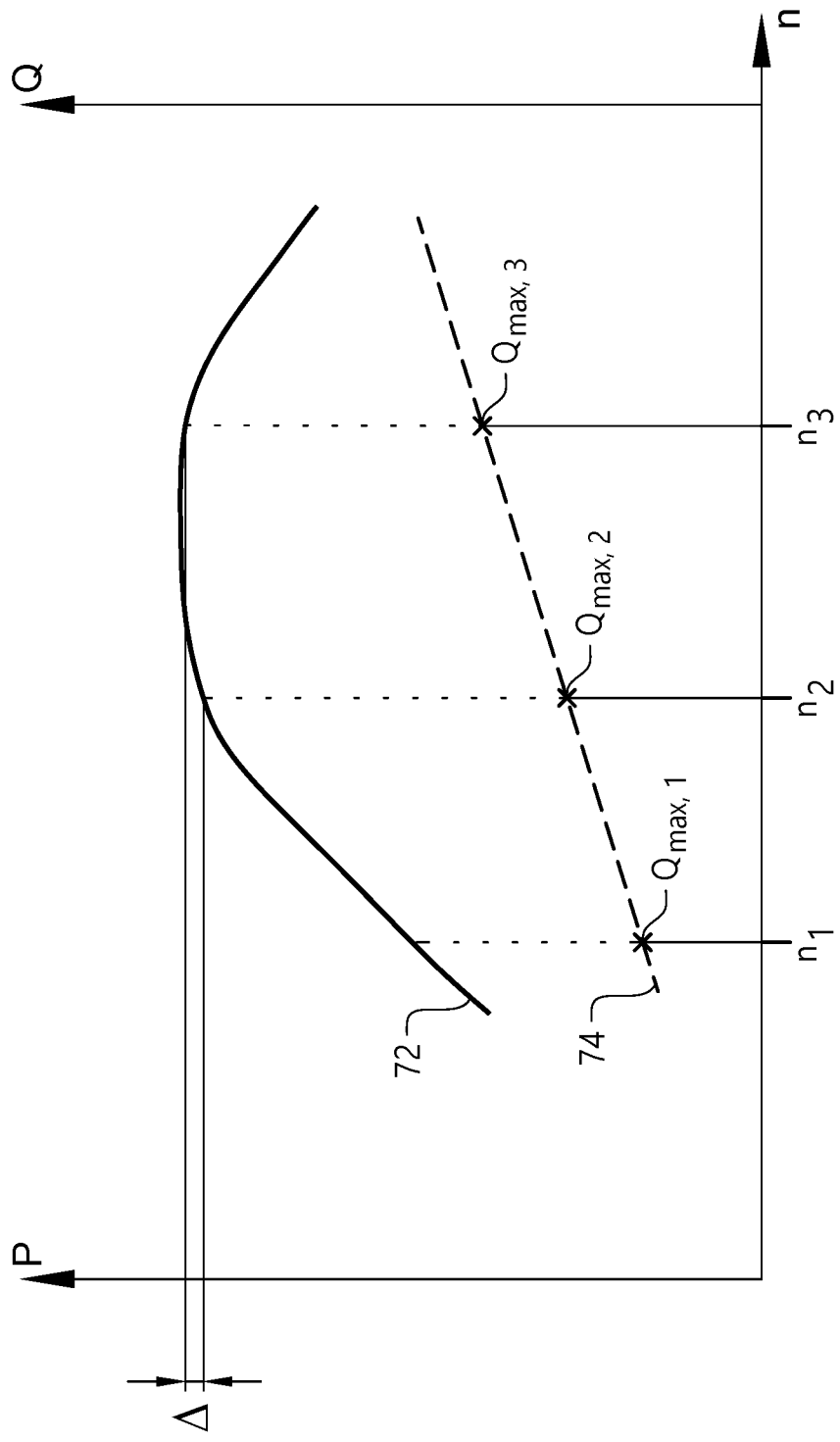


FIG. 5

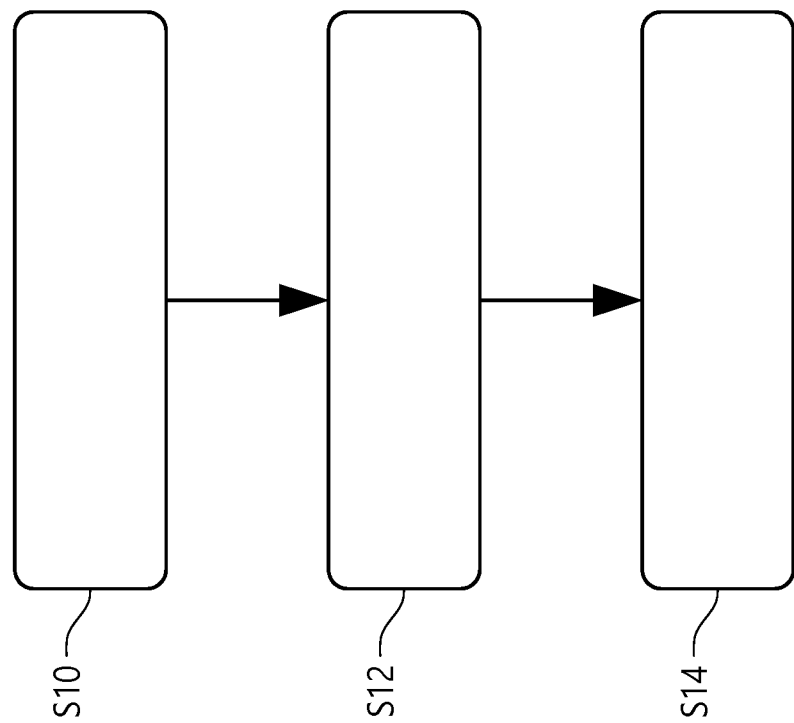
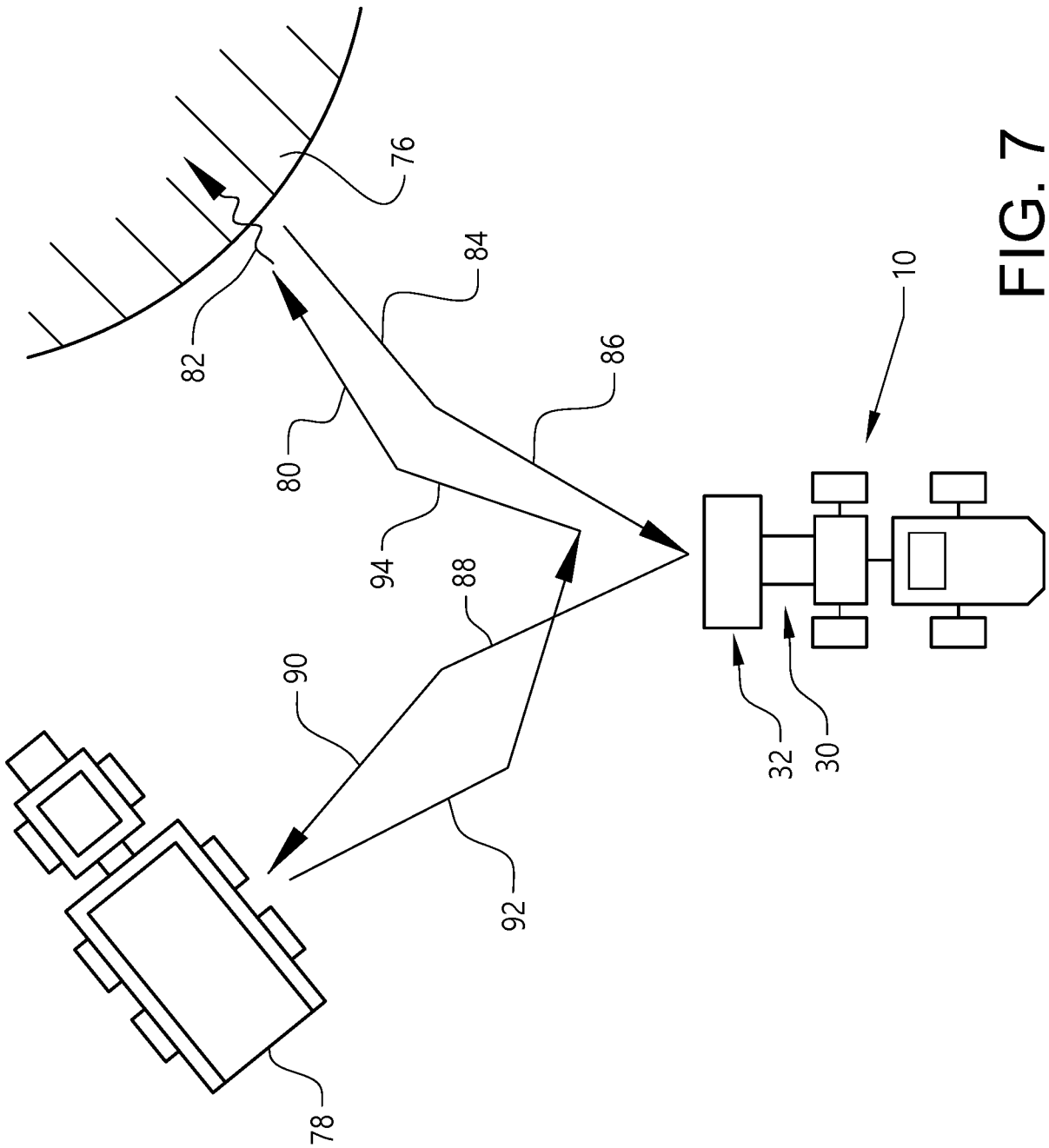


FIG. 6



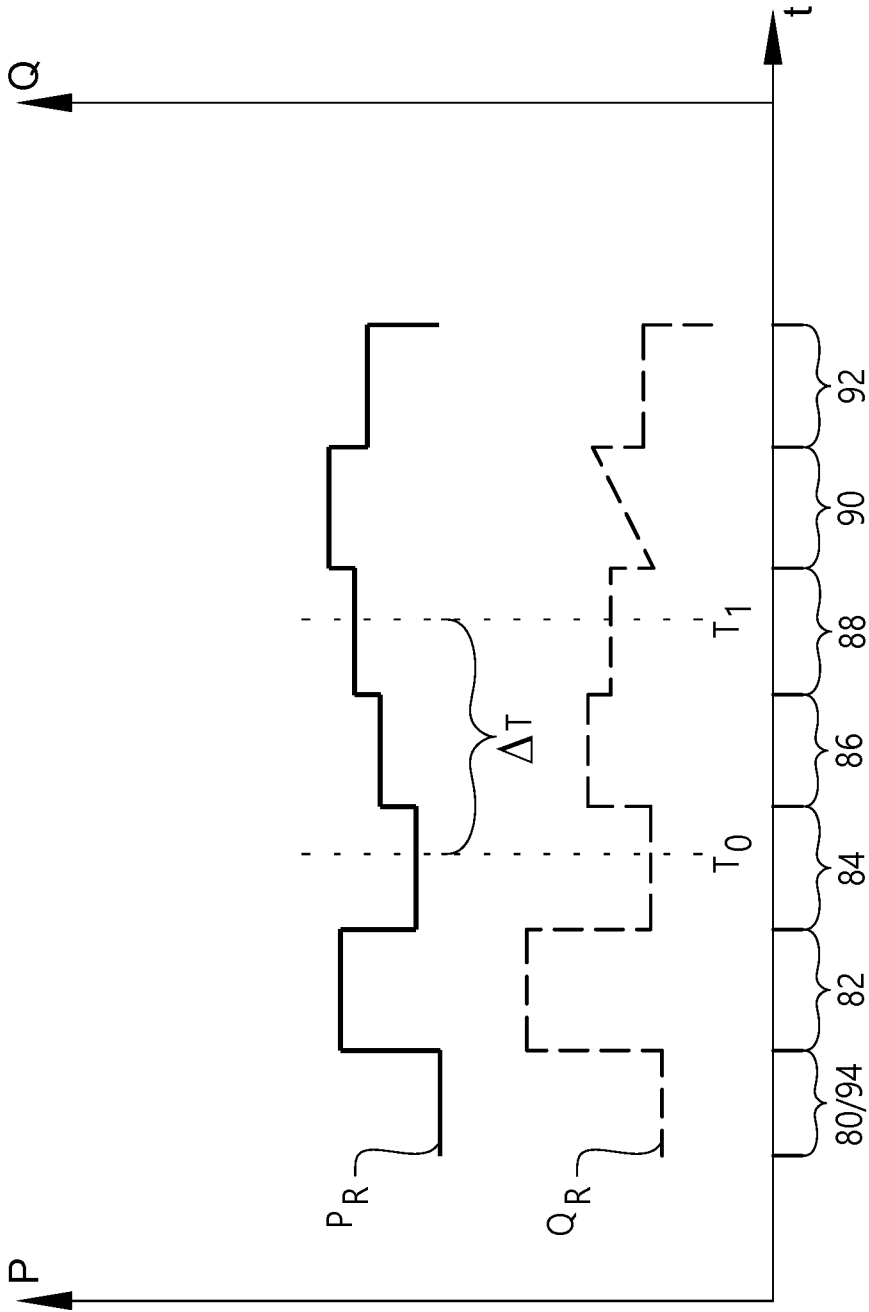


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/057968

A. CLASSIFICATION OF SUBJECT MATTER
INV. E02F9/22 E02F9/20 B60W10/06
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)
E02F 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.
X	WO 2008/100185 A1 (VOLVO CONSTR EQUIP AB [SE]; EKVALL ANDREAS [SE]; KARLSSON JAN [SE]) 21 August 2008 (2008-08-21)	1-10, 15-19
A	the whole document	11-14
A	EP 2 982 849 A1 (KOMATSU MFG CO LTD [JP]) 10 February 2016 (2016-02-10) abstract; figures 1-16	1-16
A	EP 1 830 053 A1 (HITACHI CONSTRUCTION MACHINERY [JP]) 5 September 2007 (2007-09-05) abstract; figures 1-6	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

21 December 2017

Date of mailing of the international search report

09/01/2018

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/057968

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 2008100185	A1	21-08-2008	CN	101636305 A	27-01-2010
			EP	2121404 A1	25-11-2009
			US	2010179735 A1	15-07-2010
			WO	2008100185 A1	21-08-2008

EP 2982849	A1	10-02-2016	CN	105229282 A	06-01-2016
			EP	2982849 A1	10-02-2016
			JP	2015140727 A	03-08-2015
			US	2016145836 A1	26-05-2016
			WO	2015114954 A1	06-08-2015

EP 1830053	A1	05-09-2007	CN	1993541 A	04-07-2007
			EP	1830053 A1	05-09-2007
			JP	4315248 B2	19-08-2009
			JP	2006169974 A	29-06-2006
			KR	20070096783 A	02-10-2007
			US	2007204605 A1	06-09-2007
			WO	2006064623 A1	22-06-2006
