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(71) Applicant(s)
Hitachi Construction Machinery Co., Ltd.

(72) Inventor(s)
Yagyu, Takashi; Tanaka, Yasuo; Watanabe, Yutaka; Nakajima, Kichio; Yasuda, Tomohiko

(74) Agent / Attorney
Davies Collison Cave, 1 Nicholson Street, Melbourne, VIC, 3000

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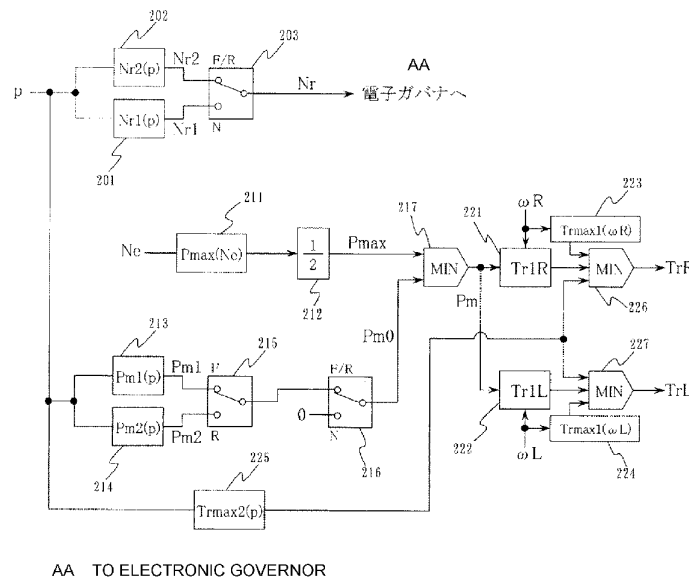
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 <i>B60W 10/30</i> (2006.01)</p> | <p>(72) 発明者: および
 (75) 発明者/出願人 (米国についてのみ): 田中 康雄
 (TANAKA, Yasuo) [JP/JP]; 〒3000013 茨城県土浦市
 神立町 6 5 0 番地 日立建機株式会社土浦工場 知的
 財産部内 Ibaraki (JP). 渡辺 豊 (WATANABE, Yutaka)
 [JP/JP]; 〒3000013 茨城県土浦市神立町 6 5 0 番地 日
 立建機株式会社土浦工場 知的財産部内 Ibaraki (JP).
 中島 吉男 (NAKAJIMA, Kichio) [JP/JP]; 〒3000013 茨
 城県土浦市神立町 6 5 0 番地 日立建機株式会社土浦
 工場 知的財産部内 Ibaraki (JP). 安田 知彦 (YASUDA,
 Tomohiko) [JP/JP]; 〒3000013 茨城県土浦市神立町
 6 5 0 番地 日立建機株式会社土浦工場 知的財産部
 内 Ibaraki (JP). 柳生 隆 (YAGYU, Takashi) [JP/JP]; 〒
 3000013 茨城県土浦市神立町 6 5 0 番地 日立建機株
 式会社土浦工場 知的財産部内 Ibaraki (JP).</p> |
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| <p>(71) 出願人 (米国を除く全ての指定国について): 日立建
 機株式会社 (HITACHI CONSTRUCTION MACHIN-
 ERY CO., LTD.) [JP/JP]; 〒1120004 東京都文京区後楽
 二丁目 5 番 1 号 Tokyo (JP).</p> | <p>(74) 代理人: 春日 譲 (KASUGA, Yuzuru); 〒1030023 東京
 都中央区日本橋本町三丁目 4 番 1 号 トリイ日本橋ビ
 ル Tokyo (JP).</p> |

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- (54) Title:** DRIVE SYSTEM FOR ELECTRICALLY DRIVEN DUMP TRUCK

- (54) 発明の名称: 電気駆動ダンプトラックの駆動システム



- (S7) Abstract:** A drive system for an electrically driven dump truck, where optimum drive characteristics are obtained for both when a hydraulic system is driven in a non-traveling state of the truck and when the truck is driven by electric motors (in a traveling state). When a shift lever (16) is at the neutral position, procedures (102-106, 125 (blocks (201-203))) calculate, based on first target rotational speed characteristics (Nr1(p)) suitable for driving a hydraulic pump for working, a target rotational speed (Nr1) corresponding to the amount (p) of operation of an accelerator pedal (1), and control an electronic governor (4a) based on the target rotational speed. When the shift lever (16) is at a forward position, the procedures calculate, based on a second target rotational speed characteristics (Nr2(p)) suitable for driving the electric motors (12R, 12L), a target rotational speed (Nr2) corresponding to the amount of operation of the accelerator pedal (1), and control an electronic governor (4a) based on this target rotational speed.

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(57) 要約: 電気駆動ダンプトラックの駆動システムにおいて、非走行時の油圧系の駆動時と電動モータ駆動時 (走行時) の双方に最適なエンジン駆動特性を得る。手順102~106, 125 (ブロック201~203) において、シフトレバー16が中立位置にあるときは、作業用の油圧ポンプの駆動に適した第1目標回転数特性 (Nr1 (p)) に基づいてアクセルペダル1の操作量 (p) に応じた目標回転数Nr1を演算し、この目標回転数に基づいて電子ガバナ4aを制御し、シフトレバー16が前進位置にあるときは、電動モータ12R, 12Lの駆動に適した第2目標回転数特性 (Nr2 (p)) に基づいてアクセルペダル1の操作量に応じた目標回転数Nr2を演算し、この目標回転数に基づいて電子ガバナ4aを制御する。

DESCRIPTION

DRIVE SYSTEM FOR ELECTRICALLY DRIVEN DUMP TRUCK

Technical Field

The present invention relates to a drive system for an electrically driven dump truck, and more particularly to a drive system for a large dump truck that drives an electric generator by a prime mover, and that drives an electric motor for traveling by the electric power so as to cause the dump truck to travel, the electric power being generated by the electric generator.

Background Art

As described in, for example, a patent document 1, a drive system for an electrically driven dump truck includes: a prime mover; an electronic governor for controlling the revolution speed and torque of the prime mover; an alternating-current generator that is driven by the prime mover; two electric motors, each of which is driven by the electric power supplied by the alternating-current generator, the two electric motors driving, for example, right and left rear wheels; two inverters, each of which is connected to the alternating-current generator, and each of which controls each of the electric motors (for example, induction motors); and a control unit for calculating the target revolution speed corresponding to the operation amount of an accelerator pedal to control the electronic governor, and

for controlling the two inverters in response to the operation amount of the accelerator pedal to control each of the electric motors.

Patent document 1: JP-A-2001-107762

Disclosure of Invention

Problems to be Solved by the Invention

In the electrically driven dump truck as described in the patent document 1, the prime mover drives not only the electric generator for driving the electric motors but also loads other than the electric generator. For example, the loads other than the electric generator includes: a hydraulic pump for moving a vessel of a dump truck up and down, and for driving hydraulic equipment used for steering operation; a cooling fan for sending air to a radiator; and a second electric generator for driving an electric fan used to cool the electric motors for traveling and a control unit.

Whether or not to cause the dump truck to travel is selected using a shift lever. When the shift lever is located at an N position (neutral position), the dump truck does not travel. Accordingly, the prime mover drives loads other than the electric generator without driving the electric generator (electric motor). The vessel is moved up and down with the shift lever being located at the N position (neutral position) (more specifically, while the dump truck is kept in a stopped state). At this time, the prime mover mainly drives the hydraulic pump. When the shift lever is located at a F position (forward position) or

a R position (reverse position), the dump truck is to travel. Accordingly, the prime mover mainly drives the electric generator (electric motor).

For the prime mover, the control unit calculates the target revolution speed corresponding to the operation amount of an accelerator pedal, and then controls an electronic governor so that the revolution speed and the torque are controlled. Heretofore, only one kind of target revolution speed characteristics is set corresponding to the operation amount of the accelerator pedal. Therefore, the one kind of target revolution speed characteristics is used for both driving of the hydraulic system (hydraulic pump) at the time of non-traveling and driving of the electric generator (electric motor) at the time of traveling.

However, at the time of driving the hydraulic pump, it is necessary to drive the prime mover over a wide revolution speed range from the minimum value to the maximum value. On the other hand, at the time of driving the electric motor, it is requested that the prime mover be driven starting from the revolution speed higher than the minimum revolution speed (for example, the revolution speed ranging from the medium speed to the revolution speed that is lower than the maximum revolution speed). By driving the prime mover over a wide revolution speed range from the minimum value to the maximum value at the time of driving the hydraulic pump, it is possible to stably operate the prime mover, and also to achieve the maximum flow of the hydraulic pump, so that the working speed can be adjusted

over a wide range. By driving the prime mover starting from the revolution speed that is higher than the minimum revolution speed (for example, the revolution speed ranging from the medium speed to the revolution speed that is lower than the maximum revolution speed) at the time of driving the electric motor, the excellent acceleration can be achieved when the accelerator pedal is pressed down. In the conventional drive system, only one kind of target revolution speed characteristics is set. Therefore, it is not possible to achieve the engine driving characteristics that are suitable for both driving of the hydraulic system and driving of the electric motor (at the time of traveling).

Embodiments of the invention may provide a drive system of an electrically driven dump truck, the drive system being capable of achieving engine driving characteristics that may be suitable for both driving of the hydraulic system and driving of the electric motor (at the time of traveling).

According to one aspect of the present invention, there is provided a drive system of an electrically driven dump truck comprising: a prime mover; an electronic governor for controlling the revolution speed and torque of the prime mover; an alternating-current generator driven by the prime mover; a hydraulic pump for working driven by the prime mover; at least two electric motors for traveling, each of

which is driven by the electric power supplied by the alternating-current generator; and at least two inverters, each of which is connected to the alternating-current generator, and each of which controls each of the electric motors; wherein the drive system comprises: an accelerator pedal; a shift lever that is operated at one of a plurality of positions including a neutral position and a forward position; motor control means for controlling the inverters to control the electric motors in response to the operation amount of the accelerator pedal; and prime mover control means for, when the shift lever is located at the neutral position, calculating a target revolution speed corresponding to the operation amount of the accelerator pedal on the basis of first target revolution speed characteristics which are suitable for driving of the hydraulic pump for working to control the electronic governor on the basis of the target revolution and for, when the shift lever is located at the forward position, calculating a target revolution speed corresponding to the operation amount of the accelerator pedal on the basis of second target revolution speed characteristics which are suitable for driving of the electric motors to control the electronic governor on the basis of the target revolution speed.

Thus, the prime mover control means is configured to set two kinds of target revolution speed characteristics (more specifically, the first target revolution speed characteristics which are suitable for driving of the

hydraulic pump for working, and the second target revolution speed characteristics which are suitable for driving of the electric motors). Therefore, it is possible to separately calculate the target revolution speed to be used when the shift lever is located at the neutral position, and the target revolution speed to be used when the shift lever is located at the forward position, to control the prime mover. This makes it possible to achieve engine driving characteristics that are suitable for both driving of the hydraulic system at the time of non-traveling and driving of the electric motors (at the time of traveling).

Preferably, the prime mover control means sets the first target revolution speed characteristics so that when the operation amount of the accelerator pedal is at 0, the target revolution speed is the specified first low-speed revolution speed, and so that with the increase in the operation amount of the accelerator pedal, the target revolution speed increases from the specified first low-speed revolution speed up to the specified first high-speed revolution speed. In addition, preferably, the prime mover control means sets the second target revolution speed characteristics so that when the operation amount of the accelerator pedal is at 0 or the specified very small amount, the target revolution speed is the specified medium-speed revolution speed which is higher than the specified first low-speed revolution speed, and so that with the increase in the operation amount of the accelerator pedal, the target revolution speed increases

from the specified medium-speed revolution speed up to the specified second high-speed revolution speed.

Thus, effects produced by setting the first and second target revolution speed characteristics may be follows: at the time of driving the hydraulic pump with the shift lever being located at the neutral position, it is possible to achieve the target revolution speed over a wide revolution speed range from the first low-speed revolution speed up to the first high-speed revolution speed, which makes it possible to stably operate the prime mover, and to achieve the maximum flow of the hydraulic pump. By this the working speed may be adjustable over a wide range; and at the time of driving the electric motors with the shift lever being located at the forward position, it may be possible to achieve the target revolution speed starting from the medium-speed revolution speed that is higher than the first low-speed revolution speed, with the possible result that the responsiveness at the time of pressing down the accelerator pedal is improved, and the excellent acceleration may be achieved.

It is desirable that the prime mover control means set the second target revolution speed characteristics so that when the operation amount of the accelerator pedal is at 0, the target revolution speed is the second low-speed revolution speed, and so that when the operation amount of the accelerator pedal becomes the specified very small amount, the target revolution speed increases up to the specified medium-speed

revolution speed step by step.

As a result, at the time of driving the electric motors (at the time of traveling) with the shift lever being located at the forward position, when the operation amount of the accelerator pedal is at 0, the target revolution speed becomes the second low-speed revolution speed. In addition to it, when the accelerator pedal is operated to a very small extent, the target revolution speed increases up to the medium-speed revolution speed step by step.

Therefore, the responsiveness (acceleration performance) at the time of pressing down the accelerator pedal is improved, and the fuel efficiency can also be improved.

(4) In addition, in the above-described item (2), it is desirable that the specified first low-speed revolution speed be the revolution speed ranging from 700 rpm to 800 rpm, and that the specified medium-speed revolution speed be the revolution speed ranging from 900 rpm to 1600 rpm, and that the specified first and second high-speed revolution speed be the revolution speed ranging from 1800 rpm to 2100 rpm.

As a result, at the time of driving the hydraulic pump with the shift lever being located at the neutral position, it is possible to obtain the target revolution speed over a wide revolution speed range from 700 rpm through 800 rpm to 1800 rpm through 2100 rpm. On the other hand, at the time of driving the electric motors with the shift lever being located at the forward position, it is possible to obtain the relatively high target revolution

speed ranging from 900 rpm through 1600 rpm.

It is desirable that the specified very small operation amount of the accelerator pedal be the operation amount ranging from 2 to 8% of the maximum operation amount of the accelerator pedal.

As a result, at the time of driving the electric motors (at the time of traveling) with the shift lever being located at the forward position, when the operation amount of the accelerator pedal is at 0, the target revolution speed may become the second low-speed revolution speed. In addition to it, when the accelerator pedal is operated to a very small extent, the target revolution speed may increase up to the medium-speed revolution speed step by step. Therefore, the responsiveness (acceleration performance) at the time of pressing down the accelerator pedal may be improved, and the fuel efficiency may also be improved.

It is desirable that the prime mover control means include: first desirable that the prime mover control means include: first target revolution speed calculation means for calculating the first target revolution speed corresponding to the operation amount of the accelerator pedal on the basis of the first target revolution speed characteristics; second target revolution speed calculation means for calculating the second target revolution speed corresponding to the operation amount of the accelerator pedal on the basis of the second target revolution speed characteristics; and target revolution speed determination means for, when the

shift lever is located at the neutral position, selecting the first target revolution speed calculated by the first target revolution speed calculation means, and for, when the shift lever is located at the forward position, selecting the second target revolution speed calculated by the second target revolution speed calculation means.

As a result, when the shift lever is located at the neutral position, the target revolution speed corresponding to the operation amount of the accelerator pedal is calculated on the basis of the first target revolution speed characteristics. On the other hand, when the shift lever is located at the forward position, the target revolution speed corresponding to the operation amount of the accelerator pedal is calculated on the basis of the second target revolution speed characteristics.

(7) Furthermore, it is desirable that the motor control means include: target motor output horsepower calculation means for calculating the first target motor output horsepower corresponding to the operation amount of the accelerator pedal; target motor torque calculation means for calculating the target motor torque on the basis of the first target motor output horsepower and the rotational speed of the two electric motors; acceleration torque limit value calculation means for calculating acceleration torque limit values of the two electric motors corresponding to the operation amount of the accelerator pedal; motor torque limiting means for limiting the target motor torque so that the target motor torque does not exceed the acceleration

torque limit value; and inverter control means for controlling the inverters on the basis of the target motor torque that is limited by the acceleration torque limit value.

As a result, at the time of normal traveling, by controlling the traveling on the basis of the target motor output horsepower that has been calculated by the target motor output horsepower calculation means, it may be possible to achieve excellent operational feeling in which the operation amount of the accelerator pedal is well balanced with the output horsepower of the electric motors. On the other hand, at the time of very slow traveling, by controlling the traveling on the basis of the acceleration torque limit values that has been calculated by the acceleration torque limit value calculation means, it may be possible to achieve excellent controllability, and to easily make a delicate positioning.

Effects of Invention

According to the present invention, the prime mover control means sets two kinds of target revolution speed characteristics (more specifically, the first target revolution speed characteristics which are suitable for driving of the hydraulic pump for working, and the second target revolution speed characteristics which are suitable for driving of the electric motors). Therefore, it is possible to separately calculate the target revolution speed to be used when the shift lever is located at the neutral

position, and the target revolution speed to be used when the shift lever is located at the forward position, to control the prime mover. This makes it possible to achieve engine driving characteristics that are suitable for both driving of the hydraulic system at the time of non-traveling and driving of the electric motor (at the time of traveling).

In addition, at the time of driving the hydraulic pump with the shift lever being located at the neutral position, the prime mover is so controlled that the prime mover is driven over a wide revolution speed range from the first low-speed revolution speed to the first high-speed revolution speed. Accordingly, it is possible to stably operate the prime mover, and to achieve the maximum flow of the hydraulic pump, so that the working speed can be adjusted over a wide range. On the other hand, at the time of driving the electric motor with the shift lever being located at the forward position, the prime mover is so controlled that the prime mover is driven starting from the medium-speed revolution speed that is higher than the first low-speed revolution speed. Accordingly, the responsiveness at the time of pressing down the accelerator pedal is improved, and the excellent acceleration can be achieved.

Brief Description of the Drawings

Fig. 1 is a diagram illustrating an overall configuration of a drive system of an electrically driven dump truck according to one embodiment of the present invention;

Fig. 2 is a functional block diagram illustrating processing steps of a drive system according to this embodiment;

Fig. 3 is a flowchart illustrating processing steps;

Fig. 4 is a flowchart illustrating processing steps;

Fig. 5 is a chart illustrating a function $Nr1(p)$ of the first target revolution speed at the time of non-traveling;

Fig. 6 is a chart illustrating a function $Nr2(p)$ of the second target revolution speed at the time of traveling;

Fig. 7 is a chart illustrating a modified example of the function $Nr2(p)$ of the second target revolution speed at the time of traveling;

Fig. 8 is a chart illustrating another modified example of the function $Nr2(p)$ of the second target revolution speed at the time of traveling;

Fig. 9 is a chart illustrating a function $Pmax(Ne)$ of the maximum motor output horsepower;

Fig. 10 is a chart illustrating a data map showing the relationship between the revolution speed and the maximum output horsepower of the prime mover, which is expressed by a function $f(Ne)$, and illustrating a data map showing the relationship between the revolution speed and the other prime mover load loss horsepower, which is expressed by a function $g(Ne)$;

Fig. 11 is a chart illustrating a function $Pm1(p)$ of the first target motor output horsepower at the time of traveling forward;

Fig. 12 is a chart illustrating a function $P_{m2}(p)$ of the second target motor output horsepower at the time of traveling backward;

Fig. 13 is a chart illustrating the relationship among the target motor output horsepower P_m , the rotational speed ω_R , ω_L of the electric motors, and the target motor torque Tr_{1R} , Tr_{1L} ;

Fig. 14 is a chart illustrating a data map showing the relationship between the motor rotational speed and the maximum motor torque, which is expressed by a function $Tr_{max1}(\omega)$ of the maximum motor torque;

Fig. 15 is a chart illustrating a function $Tr_{max2}(p)$ of the motor acceleration torque;

Fig. 16 is a chart illustrating the result of selecting the minimum value between the target motor torque Tr_{1R} , Tr_{1L} and the motor acceleration torque Tr_{max2} ;

Fig. 17 is a functional block diagram illustrating processing steps of a drive system according to a second embodiment;

Fig. 18 is a flowchart illustrating processing steps according to the second embodiment; and

Fig. 19 is a chart illustrating a function $K_{max}(p)$ of a motor torque limit ratio.

Description of Reference Numbers

- 1: Accelerator pedal
- 2: Retard pedal
- 3: Total control unit
- 4: Prime mover (diesel engine)

5: Alternating-current generator
 6: Rectifying circuit
 7: Inverter control unit
 8: Chopper circuit
 9: Grid resistor
 10: Capacitor
 11: Resistor for detecting the voltage after rectification
 12R, 12L: Right and left electric motors (induction motors)
 13R, 13L: Speed reducer
 14R, 14L: Right and left rear wheels (tires)
 15R, 15L: Electromagnetic pickup sensors
 16: Shift lever
 18: Other prime mover loads
 71R, 71L: Torque instruction operation units
 72R, 72L: Motor control operation units
 73R, 73L: Inverters (switching elements)
 Nr1: First target revolution speed
 Nr2: Second target revolution speed
 Nr: Target revolution speed
 Pm1: First target motor output horsepower
 Pm2: Second target motor output horsepower
 Pm0: Target motor output horsepower
 Pmax: Upper limit of the motor output horsepower
 Pm: Target motor output horsepower
 Tr1R, Tr1L: Target motor torque
 Trmax2: Motor acceleration torque
 Trmax: Maximum allowable motor torque
 TrR, TrL: Motor torque instruction value

Function Nr1(p): First target revolution speed characteristics

Function Nr2(P): Second target revolution speed characteristics

Function Trmax2(p): Acceleration torque limit value characteristics

Best Modes for Carrying out the Invention

One embodiment of the present invention will be described with reference to drawings as below.

Fig. 1 is a diagram illustrating an overall configuration of a drive system for an electrically driven dump truck according to one embodiment of the present invention.

In Fig. 1, the drive system for the electrically driven dump truck includes: an accelerator pedal 1; a retard pedal 2; a shift lever 16; a total control unit 3; a prime mover 4; an alternating-current generator 5; other prime mover loads 18; a rectifying circuit 6; an inverter control unit 7; a chopper circuit 8; a grid resistor 9; a capacitor 10; a resistor 11; right and left electric motors (for example, induction motors) 12R, 12L; speed reducers 13R, 13L; tires 14R, 14L; and electromagnetic pickup sensors 15R, 15L. The inverter control unit 7 includes: torque instruction operation units 71R, 71L that are used for the right and left electric motors 12R, 12L respectively; motor control operation units 72R, 72L; and inverters (switching elements) 73R, 73L.

A manipulate signal p of the accelerator pedal 1 and a manipulate signal q of the retard pedal 2 are inputted into the total control unit 3. The manipulate signals p and q become a signal for controlling the magnitude of the driving force, and a signal for controlling the magnitude of the retard force, respectively.

When a dump truck is moved forward or backward, an accelerator pedal 1 is pressed down with a shift lever 16 being located at a forward or reverse position. In response to it, a total control unit 3 issues, to a prime mover 4, an instruction indicating the target revolution speed N_r . As a result, a signal indicating the actual rotation speed N_e is returned from the prime mover 4 to the control unit 3. The prime mover 4 is a diesel engine that is equipped with an electronic governor 4a. When the electronic governor 4a receives an instruction indicating the target revolution speed N_r , the electronic governor 4a controls the fuel injection amount so that the prime mover 4 revolves at the target revolution speed N_r .

The alternating-current generator 5 is connected to the prime mover 4. The alternating-current generator 5 performs alternating current generation. The electric power obtained by the alternating current generation is rectified by the rectifying circuit 6 before the electric power is accumulated in the capacitor 10. A direct-current voltage value becomes V. The alternating-current generator 5 feeds back a voltage value, into which the direct-current voltage V is divided by the detection resistor 11. The total

control unit 3 controls the alternating-current generator 5 so that the voltage value in question becomes a specified constant voltage V_0 .

The electric power generated by the alternating-current generator 5 is supplied to the right and left electric motors 12R, 12L through the inverter control unit 7. By controlling the alternating-current generator 5 so that the direct-current voltage V which has been rectified by the rectifying circuit 6 becomes the specified constant voltage V_0 , the total control unit 3 controls the supply of the electric power so that the electric power required for the electric motors 12R, 12L is supplied.

The horsepower M_R , M_L of the right and left electric motors 12R, 12L, which is instructed from the total control unit 3, and the rotational speed ω_R , ω_L of the electric motors 12R, 12L, which is detected by the electromagnetic pickups 15R, 15L, are inputted into the inverter control unit 7. Then, the inverter control unit 7 drives the electric motors 12R, 12L at a slip ratio of greater than 0 through the torque instruction operation units 71R, 71L, the motor control operation units 72R, 72L, and the inverters (switching elements) 73R, 73L respectively.

The right and left rear wheels (tires) 14R, 14L are connected to the electric motors 12R, 12L through the speed reducers 13R, 13L respectively. The electromagnetic pickups 15R, 15L are typically sensors for detecting the peripheral speed of one gear teeth included in the speed reducers 13R, 13L respectively. In addition, for example, if the right

side driving system is taken as an example, a gear used for detection may also be given to a driving shaft inside the electric motor 12R, or to a driving shaft to which the speed reducer 13R and the tire 14R are connected, so that the electromagnetic pickup 15R is located at the position of the gear.

When the accelerator pedal 1 is released to press down on the retard pedal 2 during traveling, the total control unit 3 controls the alternating-current generator 5 so that the alternating-current generator 5 does not generate electricity. Moreover, because the horsepower instructions MR, ML issued from the total control unit 3 become negative, the inverter control unit 7 applies the brake force to a car body which travels by driving each of the electric motors 12R, 12L at a slip ratio of less than 0. At this time, each of the electric motors 12R, 12L acts as an electric generator. Accordingly, each of the electric motors 12R, 12L works so that the capacitor 10 is charged by a rectifying function that is built-into the inverter control unit 7. The chopper circuit 8 works so that the direct-current voltage value V becomes less than a predetermined direct-current voltage value V_1 . As a result, an electric current is fed to the grid resistor 9 to transform the electric energy into the thermal energy.

The prime mover 4 drives not only the alternating-current generator 5 but also components including: a hydraulic pump 18a (hereinafter referred to as a "hydraulic pump for working") for driving a hydraulic system that is

used to move a vessel of the dump truck up and down, and that is used to perform steering operation; a cooling fan (not illustrated) used for sending air to a radiator; and a second electric generator (not illustrated) for driving an electric fan (not illustrated) that is used to cool the alternating-current generator 5, the grid resistor 9, the electric motors 12R, 12L, the control units 3, 7, and the like. In Fig. 1, these components are illustrated as the other prime mover loads 18.

Up to this point, the basic configuration of the usual electrically driven dump truck has been described.

Next, characteristic part of the present invention will be described.

According to the present invention, operation of each component is subjected to arithmetic processing according to processing steps stored in a memory, which is not illustrated. The memory is built into the total control unit 3 and the inverter control unit 7. Fig. 2 is a functional block diagram illustrating the processing steps. Figs. 3, 4 are flowcharts each illustrating the processing steps. The processing steps will be described mainly according to Fig. 3 and the flowchart shown in Fig. 3, and supplementarily by use of the functional block diagram shown in Fig. 2, as below.

According to the process flow shown in Figs. 3, 4, the process starts from START; and when the processing steps are performed up to END, the process returns to START again.

In a step 101, the following information is read out:

the state quantity S indicating a switching position of the shift lever 16; the operation amount p of the accelerator pedal (hereinafter referred to as "the accelerator operation amount"); the actual revolution speed N_e of the prime mover 4; and the rotational speed ω_R , ω_L of the electric motors for traveling 12R, 12L (hereinafter referred to as "the motor rotational speed"). There are three switching positions of the shift lever 16, which are N (neutral), F (forward), and R (reverse).

In a step 102, the first target revolution speed N_{r1} corresponding to the accelerator operation amount p , which has been read out in the step 101, is calculated with reference to a data map showing the relationship between the accelerator operation amount and the target prime mover revolution speed, the data map being expressed by a function $N_{r1}(p)$ (shown in Fig. 5) of the first target revolution speed to be used while the dump track is not traveling (block 201 shown in Fig. 2).

The function $N_{r1}(p)$ expresses the first target revolution speed characteristics that are suitable for driving of the hydraulic pump 18a for working. In Fig. 5, the function $N_{r1}(p)$ is configured as follows: when the operation amount of the accelerator pedal 1 is at 0, which means no operation, the first target revolution speed N_{r1} is at the minimum revolution speed N_{r1min} of the prime mover 4 (that is to say, the first target revolution speed N_{r1} is equivalent to the idle revolution speed); when the accelerator operation amount p falls within a range from 0

to the operation amount p_a that is smaller than the maximum operation amount p_{max} , the first target revolution speed $Nr1$ increases from the minimum revolution speed $Nr1min$ up to the maximum revolution speed $Nr1max$ with the increase in the operation amount p of the accelerator pedal 1; and if the accelerator operation amount p exceeds the operation amount p_a , the first target revolution speed $Nr1$ becomes constant at the maximum revolution speed $Nr1max$. The minimum revolution speed $Nr1min$ is, for example, the revolution speed ranging from 700 rpm to 800 rpm. In the example illustrated in the figure, the minimum revolution speed $Nr1min$ is 750 rpm. It is desirable that the maximum revolution speed $Nr1max$ be the maximum rated revolution speed of the prime mover 4. For example, the maximum revolution speed $Nr1max$ is the revolution speed ranging from 1800 rpm to 2100 rpm. In the example illustrated in the figure, the maximum revolution speed $Nr1max$ is 1900 rpm.

In addition, it is desirable that the operation amount p_a , which is smaller than the maximum operation amount p_{max} , range from 80% to 95% of the maximum operation amount p_{max} . In the example illustrated in the figure, the operation amount p_a is 90% of the maximum operation amount p_{max} .

In a step 103, the second target revolution speed $Nr2$ corresponding to the accelerator operation amount p , which has been read out in the step 101, is calculated with reference to a data map showing the relationship between the accelerator operation amount and the target prime mover

revolution speed, the data map being expressed by a function $Nr2(p)$ (shown in Fig. 6) of the second target revolution speed to be used while the dump track is traveling (block 202 shown in Fig. 2).

The function $Nr2(p)$ expresses the second target revolution speed characteristics that are suitable for driving of the electric motors 12R, 12L. In Fig. 6, the function $Nr2(p)$ is configured as follows: when the operation amount of the accelerator pedal 1 ranges from 0, which means no operation, to the very small operation amount $Pb1$, the second target revolution speed $Nr2$ is at the minimum revolution speed $Nr2min$ (that is to say, the second target revolution speed $Nr2$ is equivalent to the idle revolution speed); if the operation amount of the accelerator pedal 1 reaches the very small operation amount $Pb1$, the second target revolution speed increases up to the medium-speed revolution speed $Nr2mid$ step by step; when the accelerator operation amount p ranges from the very small operation amount $Pb1$ to the medium operation amount $Pb2$, the second target revolution speed $Nr2$ increases from the medium-speed revolution speed $Nr2mid$ up to the maximum revolution speed $Nr2max$ with the increase in the accelerator operation amount p ; and if the accelerator operation amount p exceeds the medium operation amount $Pb2$, the second target revolution speed $Nr2$ becomes constant at the maximum revolution speed $Nr2max$. As is the case with the function $Nr1(p)$, the minimum revolution speed $Nr2min$ is, for example, the revolution speed ranging from 700 rpm to 800 rpm. In the

example illustrated in the figure, the minimum revolution speed $Nr2min$ is 750 rpm. It is desirable that the maximum revolution speed $Nr2max$ be the revolution speed ranging from 1800 rpm to 2100 rpm. In the example illustrated in the figure, the maximum revolution speed $Nr2max$ is 1900 rpm, which is the maximum rated revolution speed, and which is the same as the maximum revolution speed $Nr1max$ of the function $Nr1(p)$. If the minimum revolution speed $Nr2min$ is 750 rpm, whereas the maximum revolution speed $Nr2rnax$ is 1900 rpm, it is desirable that the medium-speed revolution speed $Nr2mid$ be the revolution speed ranging from 900 rpm to 1600 rpm. In the example illustrated in the figure, the medium-speed revolution speed $Nr2mid$ is 1300 rpm. Even if the minimum revolution speed $Nr2min$ is set at a value other than 750 rpm, and even if the maximum revolution speed $Nr2max$ is set at a value other than 1900 rpm, it is possible to define the medium-speed revolution speed $Nr2mid$ as the revolution speed ranging from 900 rpm to 1600 rpm.

In addition, it is desirable that the very small operation amount $Pb1$ range from 2 to 8% of the maximum operation amount $Pmax$ of the accelerator pedal. In the example illustrated in the figure, the very small operation amount $Pb1$ is 5% of the maximum operation amount $pmax$. It is desirable that the medium operation amount $Pb2$ range from 30 to 70% of the maximum operation amount $Pmax$. In the example illustrated in the figure, the medium operation amount $Pb2$ is 40% of the maximum operation amount $Pmax$.

Figs. 7, 8 are charts each illustrating a modified

example of the function $Nr2(p)$ at the time of traveling. In the example shown in Fig. 6, the maximum revolution speed $Nr2max$ of the traveling-time function $Nr2(p)$ is set at the same value as that of the maximum revolution speed $Nr1max$ of the non-traveling-time function $Nr1(p)$. However, as shown in Fig. 7, the maximum revolution speed $Nr2max$ of the traveling-time function $Nr2(p)$ may also be set at a value of for example 1800 rpm, which is smaller than the maximum revolution speed $Nrmax$ of the function $Nr1(p)$ (the maximum rated revolution speed). In addition, in the example shown in Fig. 6, it is so configured that when the operation amount of the accelerator pedal 1 ranges from 0 to the very small operation amount $Pb1$, the second target revolution speed $Nr2$ becomes the minimum revolution speed $Nr2min$. However, as shown in Fig. 8, the operation amount range within which the second target revolution speed $Nr2$ becomes the minimum revolution speed $Nrmin$ may also be eliminated. In the example shown in Fig. 10, it is so configured that when the operation amount of the accelerator pedal 1 is at 0, the second target revolution speed Nr immediately becomes the medium-speed revolution speed $Nr2mid$ that is higher than the idle revolution speed, and that the second target revolution speed $Nr2$ then increases from the medium-speed revolution speed $Nr2mid$ up to the maximum revolution speed $Nr2max$ with the increase in the accelerator operation amount p from 0 to the medium operation amount $Pb2$.

In steps 104 through 106, if the state quantity S of the shift lever 16, which has been read out in the step 101,

is N (neutral), the target revolution speed N_r of the prime mover 4 is set at N_{r1} ($N_r = N_{r1}$). On the other hand, if the state quantity S of the shift lever 16 is F (forward) or R (reverse), the target revolution speed N_r of the prime mover 4 is set at N_{r2} ($N_r = N_{r2}$) (block 203 shown in Fig. 2).

In a step 111, on the basis of the actual revolution speed N_e of the prime mover 4 that has been read out in the step 101, the corresponding available maximum horsepower M_r for the electric motors 12R, 12L is calculated with reference to a data map showing the relationship between the engine revolution speed and the maximum motor output horsepower, the data map being expressed by a function $M_r(N_e)$ of the maximum motor output horsepower shown in Fig. 9. Then, the maximum horsepower M_r is multiplied by $1/2$ to calculate the output horsepower upper limit P_{max} per one electric motor 12R or 12L (blocks 211, 212 shown in Fig. 2).

In Fig. 9, the function $M_r(N_e)$ is so configured that with the increase in the actual revolution speed N_e of the prime mover 4 (hereinafter referred to as "the engine revolution speed"), the available maximum horsepower M_r for the electric motors 12R, 12L (hereinafter referred to as the maximum motor output horsepower) increases.

How to set the function $M_r(N_e)$ of the maximum motor output horsepower will be described.

Fig. 10 is a chart illustrating a data map showing the relationship between the revolution speed and the maximum output horsepower of the prime mover, which is expressed by a function $f(N_e)$, and illustrating a data map

showing the relationship between the revolution speed and the other prime mover load loss horsepower, which is expressed by a function $g(N_e)$.

The function $f(N_e)$ is used to determine the maximum output horsepower that can be generated by the prime mover 4. Here, the function $f_1(N_e)$, the function $f_2(N_e)$, and the function $f_3(N_e)$ are combined into the function $f(N_e)$. The function $f_1(N_e)$ is equivalent to the function $f_r = f(N_r)$ based on the relationship between the target revolution speed N_r and the output horsepower of the prime mover 4. If the engine revolution speed N_e changes from N_{rmin} (for example, 750 rpm) up to N_{rmax} (for example, 2000 rpm), the maximum output horsepower $f(N_e)$ which can be generated by the prime mover 4 changes from the minimum value F_{min} up to the maximum value F_{max} . This is a diagram illustrating a characteristic line that is specific to the prime mover 4. The function $f_2(N_e)$ is based on the assumption that the maximum output horsepower $f(N_e)$ of the prime mover 4 is kept at a constant value of $f_2 = F_{min}$ within a range of $0 \leq N_e < N_{rmin}$. The function $f_3(N_e)$ is based on the assumption that the maximum output horsepower $f(N_e)$ of the prime mover 4 is kept at a constant value of $f_3 = F_{max}$ within a range of $N_{rmax} < N_e \leq N_{emax}$.

The prime mover 4 drives not only the alternating-current generator 5 but also the other prime mover loads 18. The other prime mover loads 18 include: a hydraulic pump 18a for moving a vessel of the dump truck up and down, and for driving a hydraulic system used for steering operation; a

cooling fan, which is not illustrated, the cooling fan being used for sending air to a radiator; and a second electric generator (not illustrated) for driving an electric fan (not illustrated) that is used to cool the alternating-current generator 5, the grid resistor 9, the electric motors 12R, 12L, and the control units 3, 7. Horsepower values, which are assigned beforehand to drive the other prime mover loads 18, are expressed by $g(N_e)$ shown in Fig. 10. The horsepower $g(N_e)$ is set at values which are slightly larger than those of the horsepower actually consumed by the other prime mover loads 18 so that a sufficient margin of the horsepower $g(N_e)$ is left. In this specification, this horsepower is called the loss horsepower.

As is the case with the function (N_e) , the function $g_1(N_e)$, the function $g_2(N_e)$, and the function $g_3(N_e)$ are combined into function $g(N_e)$ of the loss horsepower. In the case of the function $g_1(N_r)$, if the engine revolution speed N_e changes from N_{rmin} (for example, 750 rpm) up to N_{rmax} (for example, 2000 rpm), the loss horsepower $g_1(N_e)$ changes from the minimum value G_{min} up to the maximum value G_{max} . The function $g_2(N_e)$ is based on the assumption that the loss horsepower $g(N_e)$ is kept at a constant value of $g_2 = G_{min}$ within a range of $0 \leq N_e < N_{rmin}$. The function $g_3(N_e)$ is based on the assumption that the loss horsepower $g(N_e)$ is kept at a constant value of $g_3 = G_{max}$ within a range of $N_{rmax} < N_e \leq N_{emax}$.

In Fig. 10, M_r , which is the difference $(f(N_e) - g(N_e))$ between $f(N_e)$ and $g(N_e)$, is the total effective

maximum horsepower that can be applied to the electric motors 12R, 12L. In other words, $M_r = (f(N_e) - g(N_e))$ is the available maximum horsepower (an assigned horsepower value) for the electric motors 12R, 12L, which are used for traveling, out of the maximum output horsepower $f(N_e)$ that can be generated by the prime mover 4. The maximum output horsepower of the electric motors 12R, 12L cannot exceed this value (more specifically, $M_r = f(N_e) - g(N_e)$).

The function $M_r(N_e)$ of the maximum motor output horsepower is set on the basis of the thought as described above. The output horsepower upper limit P_{max} per one electric motor 12R or 12L is expressed by the following equation:

$$P_{max} = M_r/2 = (f(N_e) - g(N_e))/2$$

In a step 112, on the basis of the accelerator operation amount p that has been read out in the step 101, the first target motor output horsepower P_{m1} corresponding to the accelerator operation amount p in question is calculated with reference to a data map showing the relationship between the accelerator operation amount and the target motor output horsepower, the data map being expressed by the function $P_{m1}(p)$ of the first target motor output horsepower at the time of traveling forward shown in Fig. 11 (block 213 shown in Fig. 2).

In Fig. 11, the function $P_{m1}(p)$ is configured as follows: if the accelerator operation amount $p = 0$, the

first target motor output horsepower $P_{m1} = 0$; in a state in which the accelerator pedal is pressed down to a small extent (more specifically, starting from a point X_1 shown in Fig. 11), P_{m1} increases; subsequently an increasing rate of P_{m1} increases from an area around a point X_2 ; and then at a point X_3 at which the accelerator operation amount is lower than the maximum value p_{max} , P_{m1} reaches the maximum horsepower P_{m1max} that can be generated by the electric motors 12R, 12L. The accelerator operation amount p_{x3} at the point X_3 shown in Fig. 11 is, for example, about 95% of the maximum operation amount p_{max} .

In a step 113, on the basis of the accelerator operation amount p that has been read out in the step 101, the second target motor output horsepower P_{m2} corresponding to the accelerator operation amount p in question is calculated with reference to a data map showing the relationship between the accelerator operation amount and the target motor output horsepower, the data map being expressed by the function $P_{m2}(p)$ of the second target motor output horsepower at the time of traveling backward (block 214 shown in Fig. 2).

In Fig. 12, the function $P_{m2}(p)$ is so configured that although the second target motor output horsepower P_{m2} increases with the increase in the accelerator operation amount p , the maximum value P_{m2rnax} of the second target motor output horsepower becomes smaller than the maximum value P_{m1max} in the function $P_{m1}(p)$ used for traveling forward. Incidentally, the target motor output horsepower

for traveling backward may also be determined by multiplying the target motor output horsepower, which has been determined by the function $Pm1(p)$ used for traveling forward, by a positive constant whose value is smaller than 1.

In steps 114 through 117, if the state quantity S of the shift lever 16, which has been read out in the step 101, is N (neutral), the target horsepower $Pm0$ of the electric motors 12R, 12L (hereinafter referred to as "the target motor output horsepower") is set at 0 ($Pm0 = 0$). If the state quantity S of the shift lever 16 is F (forward), the target horsepower $Pm0$ of the electric motors 12R, 12L (hereinafter referred to as "the target motor output horsepower") is set at $Pm1$ ($Pm0 = Pm1$). If the state quantity S of the shift lever 16 is R (reverse), the target motor output horsepower $Pm0$ is set at $Pm2$ ($Pm0 = Pm2$) (blocks 215, 216 shown in Fig. 2).

In a step 118, the smaller value is selected between the motor output horsepower upper limit $Pmax$ and the target motor output horsepower $Pm0$ so that the selected value is used as the target motor output horsepower Pm (block 217 shown in Fig. 4).

$$Pm = \min(Pmax, Pm0)$$

To be more specific, in the step 118 (block 217 shown in Fig. 4), the target motor output horsepower Pm which is applied to the electric motors 12R, 12L is limited so that the target motor output horsepower Pm does not become $Pmax$

or more. This target motor output horsepower P_m corresponds to the instructed horsepower M_R , M_L shown in Fig. 1 ($M_R = M_L = P_m$).

In a step 121, the target motor torque $Tr1R$, $Tr1L$ is calculated from the target motor output horsepower P_m , and the rotational speed ω_R , ω_L of the electric motors 12R, 12L, which has been read out in the step 101, by the following equations respectively (blocks 221, 222 shown in Fig. 4).

$$Tr1R = K1 \times P_m / \omega_R$$

$$Tr1L = K1 \times P_m / \omega_L$$

$K1$: Constant used to calculate the torque from the horsepower and the revolution speed.

Fig. 13 is a chart illustrating the relationship among the target motor output horsepower P_m , the rotational speed ω_R , ω_L of the electric motors 12R, 12L, and the target motor torque $Tr1R$, $Tr1L$. If the target motor output horsepower P_m is determined, the target motor torque $Tr1R$, $Tr1L$ in response to the motor rotational speed ω_R , ω_L at this point of time is determined respectively. For example, when the motor rotational speed ω_R , ω_L is ω_1 , the target motor torque becomes $Tr1R = P_m((\omega_1))$, $Tr1L = P_m((\omega_1))$ respectively. Moreover, for example, when the dump truck comes to an upward slope, the load torque of the electric motors 12R, 12L increases, and accordingly the motor rotational speed ω_R , ω_L decreases, with the result that the target motor torque $Tr1R$, $Tr1L$ increases in response to the

increase in load torque respectively. In contrast with this, when the load torque of the electric motors 12R, 12L decreases, the target motor torque $Tr1R$, $Tr1L$ decreases respectively. On the other hand, if the target motor output horsepower P_m is increased, the target motor torque $Tr1R$, $Tr1L$ increases in response to the increase in target motor horsepower P_m respectively. If the motor load torque at this point of time is constant, the motor rotational speed ω_R , ω_L increases respectively. In contrast with this, if the target motor output horsepower P_m is decreased in a state in which the motor load torque is kept constant, the motor rotational speed ω_R , ω_L decreases respectively.

In a step 122, on the basis of the rotational speed ω_R , ω_L of the electric motors 12R, 12L, which has been read out in the step 101, the maximum motor torque $Trmax1$ corresponding to the rotational speed ω_R , ω_L in question is calculated with reference to a data map showing the relationship between the motor rotational speed and the maximum motor torque, the data map being expressed by a function $Trmax1(\omega)$ of the maximum motor torque shown in Fig. 14 (blocks 223, 224 shown in Fig. 4).

In Fig. 14, the function $Trmax1(\omega)$ is configured on the basis of specifications of units constituting the drive system. The specifications include: the maximum value of current which the inverters 73R, 73L can supply to the electric motors 12R, 12L; an output limit of a driver element such as IGBT or GTO included in the inverters 73R, 73L; and the intensity of each motor shaft. As shown in Fig.

14, for example, when the motor rotational speed ω_R , ω_L is ω_1 , the maximum motor torque Tr_{max1} becomes $Tr_{max1}(\omega_1)$. The maximum value of the maximum motor torque Tr_{max1} is Tr_{max} .

In a step 123, on the basis of the accelerator operation amount p that has been read out in the step 101, the motor acceleration torque Tr_{max2} corresponding to the accelerator operation amount p in question is calculated with reference to a data map showing the relationship between the accelerator operation amount and the motor acceleration torque, the data map being expressed by a function $Tr_{max2}(p)$ of the motor acceleration torque (block 225 shown in Fig. 4).

The function $Tr_{max2}(p)$ expresses characteristics of an acceleration torque limit value.

In Fig. 15, the function $Tr_{max2}(p)$ is configured as follows: when the operation amount of the accelerator pedal 1 is at 0, which means no operation, the motor acceleration torque Tr_{max2} falls within a low torque range that is suitable for very slow traveling (preferably, the motor acceleration torque Tr_{max2} is kept at the minimum torque Tr_{max2a}); when the operation amount p of the accelerator pedal is within a range from 0 to the medium operation amount p_{c1} , which includes a very small operation amount area, with the increase in the accelerator operation amount p , the motor acceleration torque Tr_{max2} increases from the minimum torque Tr_{max2a} up to the higher torque Tr_{max2b} which falls within a high torque range that is suitable for very

slow traveling; when the accelerator operation amount p is within a range from the medium operation amount $pc1$ to the operation amount $pc2$ that is smaller than the maximum operation amount $pmax$, with the increase in the accelerator operation amount p , the motor acceleration torque $Trmax2$ increases from the torque $Trmax2b$ to the maximum torque $Trmax$, which is the maximum value of the maximum motor torque $Trmax1$ shown in Fig. 14, at an increasing rate that is higher than that within the range from 0 to the operation amount $pc1$; and if the accelerator operation amount p exceeds $pc2$, the motor acceleration torque $Trmax2$ becomes constant at the maximum value $Trmax$. The torque range which is suitable for very slow traveling is considered to be a range from about 15% to 50% of the maximum value $Trmax$ (the maximum allowable motor torque) of the maximum motor torque $Trmax1$ shown in Fig. 14. It is desirable that the minimum torque $Trmax2a$ at this point of time range from 15% to 30% of the maximum value $Trmax$. In the example illustrated in the figure, the minimum torque $Trmax2a$ is 20% of the maximum value $Trmax$. It is desirable that the higher torque $Trmax2b$, which falls within the high torque range suitable for very slow traveling, range from 30% to 50% of the maximum value $Trmax$. In the example illustrated in the figure, the higher torque $Trmax2b$ is 40% of the maximum value $Trmax$.

It is desirable that the medium operation amount $pc1$ range from 40% to 60% of the maximum operation amount $pmax$. In the example illustrated in the figure, the medium operation amount $pc1$ is 50% of the maximum operation amount

pmax. It is desirable that the operation amount pc2 at which the motor acceleration torque Trmax2 becomes the maximum range from 70% to 95% of the maximum operation amount pmax. In the example illustrated in the figure, the operation amount pc2 is 80% of the maximum operation amount pmax.

In a step 124, comparisons are made among the target motor torque Tr1R, Tr1L determined in the step 121, the maximum motor torque Trmax1 determined in the step 122, and the motor acceleration torque Trmax2 determined in the step 123 to select the minimum values among them so that the selected values are used as motor torque instruction values TrR, TrL respectively (blocks 226, 227 shown in Fig. 4).

To be more specific,

$$\text{TrR} = \min(\text{Tr1R}, \text{Trmax1}, \text{Trmax2})$$

$$\text{TrL} = \min(\text{Tr1L}, \text{Trmax1}, \text{Trmax2})$$

In a step 125, the target engine revolution speed Nr, which has been determined in the step 105 or 106, is transmitted to the electronic governor 4a of the prime mover 4 as an instruction.

The processing performed in the steps 101 through 118 (the blocks 201 through 217 shown in Fig. 4), the processing performed in the step 123 (the block 225 shown in Fig. 3), and the processing performed in the step 125 are processing performed by the total control unit 3. On the other hand, the processing performed in the steps 121, 122, 124 (the

blocks 221 through 224, and the blocks 226, 227, shown in Fig. 4) is processing performed by the torque instruction operation units 71R, 71L of the inverter control unit 7.

In a step 126, the motor torque instruction values TrR , TrL , which have been determined by the motor control operation units 72R, 72L included in the inverter control unit 7 in the step 123, are transmitted to the inverters 73R, 73L as instructions so that the torque of the electric motors 12R, 12L is controlled respectively.

In the above description, the processing performed in the steps 111 through 124, and 126 (the blocks 211 through 227) forms motor control means for controlling the inverters 73R, 73L in response to the operation amount of the accelerator pedal 1, and thereby for controlling the electric motors 12R, 12L respectively. The processing performed in the steps 102 through 106, and 125 (the blocks 201 through 203) forms prime mover control means including the steps of: when the shift lever 6 is located at the neutral position, calculating the target revolution speed corresponding to the operation amount of the accelerator pedal 1 on the basis of first target revolution speed characteristics (the function $Nr1(p)$) which are suitable for driving of the hydraulic pump for working to control the electronic governor 4a on the basis of this target revolution speed; and when the shift lever 6 is located at the forward position, calculating the target revolution speed corresponding to the operation amount of the accelerator pedal 1 on the basis of second target revolution

speed characteristics (the function $Nr2(p)$) which are suitable for driving of the electric motors 12R, 12L to control the electronic governor 4a on the basis of this target revolution speed.

The step 102 (the block 201) forms first target revolution speed calculation means for calculating the first target revolution speed $Nr1$ corresponding to the operation amount of the accelerator pedal 1 on the basis of the first target revolution speed characteristics. The step 103 (the block 202) forms second target revolution speed calculation means for calculating the second target revolution speed $Nr2$ corresponding to the operation amount of the accelerator pedal 1 on the basis of the second target revolution speed characteristics. The steps 104 through 106 (the block 203) form target revolution speed determination means for, when the shift lever 16 is located at the neutral position N, selecting the first target revolution speed $Nr1$ calculated by the first target revolution speed calculation means, and for, when the shift lever 16 is located at the forward position F, selecting the second target revolution speed $Nr2$ calculated by the second target revolution speed calculation means.

Moreover, in the above description, the processing performed in the steps 112 through 117 (the blocks 213 through 216) forms target motor output horsepower calculation means for calculating the target motor output horsepower $Pm0$ corresponding to the operation amount of the accelerator pedal 1. The processing performed in the step

121 (the blocks 221, 222) forms target motor torque calculation means for calculating the target motor torque $Tr1R$, $Tr1L$ on the basis of the target motor output horsepower $Pm0$ and the rotational speed ωR , ωL of the electric motors 12R, 12L respectively. The processing performed in the step 123 (the block 225) forms acceleration torque limit value calculation means for calculating acceleration torque limit values (the motor acceleration torque $Trmax2$) of the electric motors 12R, 12L corresponding to the operation amount of the accelerator pedal 1. The processing performed in the step 124 (the blocks 226, 227) forms motor torque instruction value determination means for, when the acceleration torque limit values (the motor acceleration torque $Trmax2$) are larger than the target motor torque $Tr1R$, $Tr1L$, selecting the target motor torque as the motor torque instruction values TrR , TrL respectively, and for, when the acceleration torque limit values (the motor acceleration torque $Trmax2$) are smaller than the target motor torque $Tr1R$, $Tr1L$, selecting the acceleration torque limit values as the motor torque instruction values TrR , TrL respectively. The processing performed in the step 126, and the torque instruction operation units 71R, 71L and the motor control operation units 72R, 72L, which are included in the inverter control unit 7, form inverter control means for controlling the inverters 73R, 73L on the basis of the motor torque instruction values TrR , TrL respectively.

Next, operation of this embodiment will be described.

1. At the time of non-traveling

At the time of non-traveling, the shift lever 16 is located at the N (neutral) position. When the shift lever 16 is located at the N (neutral) position, the target horsepower $Pm0$ of the electric motors 12R, 12L is equivalent to 0 ($Pm0 = 0$). Accordingly, the motors are not driven.

On the prime mover side, a data map based on the function $Nr1(p)$ of the first target revolution speed at the time of non-traveling shown in Fig. 5 is selected. Accordingly, the first target revolution speed $Nr1$ determined by the function $Nr1(p)$ is provided as the target revolution speed Nr of the prime mover 4. Therefore, at the time of non-operation in which the accelerator pedal 1 is not pressed down, the target revolution speed Nr of the prime mover 4 becomes 750 rpm, which is the idle revolution speed. This makes it possible to minimize the fuel consumption, and to improve the fuel efficiency. In addition, when the accelerator pedal 1 is pressed down, the target revolution speed Nr of the prime mover 4 increases from 750 rpm up to 1900 rpm, which is the rated revolution speed, in response to the extent to which the accelerator pedal 1 is pressed down. This causes the revolution speed of the prime mover 4 to change over a wide range from the minimum value to the maximum value. As a result, when the dump truck is stopped to execute work with only a hydraulic system being operated (for example, at the time of moving up a vessel), it is possible to stably operate the prime mover 4, and to achieve the maximum flow of the hydraulic pump 18a, so that the working speed can be adjusted over a wide range.

2. At the time of normal traveling

At the time of normal traveling, the shift lever 16 is located at the F (forward) position. When the shift lever 16 is located at the F (forward) position, a data map based on the function $Pm1(p)$ of the first target motor output horsepower at the time of forward traveling shown in Fig. 11, which has been calculated in the step 112, is selected on the electric motor side. Accordingly, the first target motor output horsepower $Pm1$ determined by function $Pm1(p)$ is provided as the target motor output horsepower $Pm0$.

On the prime mover side, a data map based on the function $Nr2(p)$ of the second target revolution speed at the time of traveling shown in Fig. 6 is selected. Accordingly, the second target revolution speed $Nr2$ determined by the function $Nr2(p)$ is provided as the target revolution speed Nr of the prime mover 4. Therefore, at the time of non-operation in which the accelerator pedal 1 is not pressed down, the target revolution speed Nr of the prime mover 4 becomes 750 rpm, which is the idle revolution speed. This makes it possible to minimize the fuel consumption, and to improve the fuel efficiency. In addition, if the accelerator pedal 1 is pressed down to a small extent at the time of starting traveling, the target revolution speed Nr of the prime mover 4 immediately increases up to 1300 rpm, which is the medium-speed revolution speed. After that, in response to the extent to which the accelerator pedal is pressed down, the target revolution speed Nr of the prime mover 4 increases from 1300 rpm up to 1900 rpm, which is the

maximum revolution speed (the rated revolution speed). As a result, the revolution speed of the prime mover 4 changes from the medium-speed revolution speed up to the maximum revolution speed with good responsiveness. Accordingly, the responsiveness at the time of pressing down the accelerator pedal 1 is improved, and the excellent acceleration performance can be achieved.

Moreover, as shown in Fig. 7, if the maximum revolution speed of the function $Nr2(p)$ is set at for example 1800 rpm, which is lower than the rated revolution speed (1900 rpm), the output horsepower of the prime mover 4 slightly decreases, which causes the traveling speed to slightly decrease. However, it is possible to reduce the fuel consumption at the time of traveling. It is also often the case that when the dump truck travels along an upslope road under conditions of mine roads with the vessel thereof being loaded with earth and sand and mined objects, the slope of the upslope road is small (for example, only about 5 to 7%). In such a case, some users request that higher priority is placed on the decrease in fuel consumption even if the traveling speed decreases to some extent. By setting the maximum revolution speed at a value that is lower than the rated revolution speed, it is possible to satisfy such user requests.

As shown in Fig. 8, if it is so configured that when the operation amount of the accelerator pedal 1 is at 0, the second target revolution speed Nr immediately becomes the medium-speed revolution speed $Nr2mid$ that is higher than the

idle revolution speed, even if the accelerator pedal is not operated, the prime mover 4 is controlled so that the prime mover 4 is kept at the medium-speed revolution speed $Nr2mid$. Accordingly, the fuel consumption increases in comparison with the example shown in Fig. 6. However, in this case, the responsiveness at the time of pressing down the accelerator pedal 1 is further improved. This makes it possible to produce an effect of further increasing the acceleration performance at the time of traveling.

In addition, on the electric motor side, when the accelerator pedal 1 is pressed down nearly to the maximum extent, in the step 123, it is possible to determine, as the motor acceleration torque $Trmax2$, the maximum value $Trmax$ of the maximum motor torque $Trmax1$ from a data map based on the function $Trmax2(p)$ of the motor acceleration torque shown in Fig. 15. Therefore, the motor acceleration torque $Trmax2$ for the control (traveling control) of the electric motors 12R, 12L is not limited. Therefore, because the electric motors 12R, 12L are controlled on the basis of the first target motor output horsepower $Pm1$ (the target motor output horsepower $Pm0$), which has been calculated in the step 112, it is possible to achieve excellent operational feeling in which the operation amount of accelerator pedal 1 is well balanced with the output horsepower of the electric motors 12R, 12L.

Moreover, on the electric motor side, in a step 111, the available maximum horsepower $Pmax$ for the electric motors 12R, 12L is calculated in response to the revolution

speed of the prime mover 4. Then, in a step 118, the target motor output horsepower P_{m0} is limited not so as to exceed the maximum horsepower P_{max} . Therefore, when acceleration is performed at the time of starting traveling, the revolution speed of the prime mover 4 does not sufficiently increase, which causes the target motor output horsepower P_{m0} to exceed the maximum horsepower P_{max} . Even in such a case, the target motor output horsepower P_{m0} is limited to the maximum horsepower P_{max} . Accordingly, it is possible to prevent the prime mover 4 from stalling.

3. At the time of very slow traveling

At the time of very slow traveling, the shift lever 16 is located at the F (forward) position. The accelerator pedal 1 is pressed down only to a small extent. At this time, on the electric motor side, the first target motor output horsepower P_{m1} on the basis of the function $P_{m1}(p)$ of the first target motor output horsepower at the time of traveling forward shown in Fig. 11 is determined as the target motor output horsepower P_{m0} . On the prime mover side, the first target revolution speed N_{r1} on the basis of the function $N_{r1}(p)$ of the first target revolution speed at the time of non-traveling shown in Fig. 6 is determined as the target revolution speed N_r of the prime mover 14. The above-described processing performed on the electric motor side, and that on the prime mover side, are the same as the processing performed at the time of normal traveling.

In addition, on the electric motor side, when the accelerator pedal 1 is pressed down only to a small extent,

if the extent to which the accelerator pedal 1 is pressed down is, for example, about 0 to 50%, a value ranging from 20 to 40% of the maximum value Tr_{max} of the maximum motor torque Tr_{max1} is determined as the motor acceleration torque Tr_{max2} on the basis of the function $Tr_{max2}(p)$ of the motor acceleration torque shown in Fig. 15. Then, in the step 124 in which the minimum value is selected from among the target torque Tr_{1R} , Tr_{1L} , the maximum motor torque Tr_{max1} , and the motor acceleration torque Tr_{max2} , the motor acceleration torque Tr_{max2} is selected as the motor torque instruction values Tr_R , Tr_L . Therefore, the traveling torque at the time of operating the accelerator pedal 1 to a very small extent, and a change in the torque, can be reduced to smaller values. This makes it possible to achieve excellent controllability, and to easily make a delicate positioning, at the time of very slow traveling.

Fig. 16 is a chart illustrating the result of selecting the minimum value between the target motor torque Tr_{1R} , Tr_{1L} and the motor acceleration torque Tr_{max2} in the step 124 (blocks 226, 227). In the figure, A, B, C, D, E correspond to points A, B, C, D, E shown in Figs. 11, 15 respectively.

When the accelerator operation amount corresponds to each of the points A, B, C, D, E shown in Fig. 11, in the step 121 (the blocks 221, 222), the target motor torque Tr_{1RA} , Tr_{1LA} through Tr_{1RE} , Tr_{1LE} (hereinafter referred to as Tr_{1A} through Tr_{1E}), which is illustrated with solid-line and broken-line hyperbolas shown in Fig. 16, is calculated

from the first target motor output horsepower corresponding to each of the points of A, B, C, D, E shown in Fig. 11, and from the function $Pm1(p)$ of the first target motor output horsepower. In addition, when the accelerator operation amount corresponds to each of the points A, B, C, D, E shown in Fig. 15, in the step 123 (the block 225), the motor acceleration torque $Trmax2A$ through $Trmax2E$, which is illustrated with solid-line straight lines shown in Fig. 16, is calculated from the function $Trmax2(p)$ of the motor acceleration torque. In the step 124 (the blocks 226, 227), a smaller value is selected from these values. As a result, the motor torque instruction values TrR , TrL become values as illustrated with the solid lines shown in Fig. 16.

In Fig. 16, the motor torque instruction values, which are illustrated in the solid lines A, B, C, are values obtained when the accelerator operation amount p is smaller than 50%. The maximum value thereof is reduced to a small value ranging from 20% to 40% of the maximum value $Trmax$ of the maximum motor torque $Trmax1$ by the motor acceleration torque $Trmax2A$ through $Trmax2C$. Moreover, as understood from, for example, the comparison between $\Delta TAB1$ and $\Delta TAB2$ ($\Delta TAB1 < \Delta TAB2$), and the comparison between $\Delta TBC1$ and $\Delta TBC2$ ($\Delta TBC1 < \Delta TBC2$), the change in motor torque instruction value corresponding to the change in the accelerator operation amount at the time of the operation of the accelerator pedal is also reduced to a value that is smaller than the amount of change in motor torque instruction value of each of the target motor torque $Tr1A$ through $Tr1E$.

Thus, by reducing the maximum value of the motor torque instruction value to a smaller value with the accelerator operation amount p being kept smaller than 50%, and by reducing the change in motor torque instruction value corresponding to the change in the accelerator operation amount at the time of operating the accelerator pedal to a smaller value, the traveling torque by the electric motors 12R, 12L at the time of operating the accelerator pedal, and a change in the traveling torque in question, become smaller, which causes a change in the traveling speed to become smaller. This makes it possible to improve the controllability at the time of very slow traveling.

As described above, according to this embodiment, when the operation amount of the accelerator pedal 1 ranges from 0 to 50%, the maximum torque for driving the electric motors 12R, 12L is reduced to a value ranging from 20 to 40%; when the operation amount of the accelerator pedal 1 is 50% or more, the maximum torque is increased; and when the operation amount of the accelerator pedal 1 nearly reaches 100%, a limit value of the maximum torque is set at 100%. As a result, at the time of normal traveling, it is possible to achieve excellent operational feeling in which the operation amount of accelerator pedal 1 is well balanced with the output horsepower of the electric motors 12R, 12L. When the operation amount of the accelerator pedal 1 is small, by limiting the torque, and the change in torque, to low values, it is possible to achieve excellent controllability at the time of very slow traveling, and to

easily make a delicate positioning.

In addition, when a hydraulic system is driven at the time of non-traveling (for example, when the vessel is moved up and down with the shift lever 15 being located at the N position without traveling), for example, the target revolution speed ranging from 750 to 1900 rpm is provided in response to the operation amount of the accelerator pedal 1. At the time of traveling during which the shift lever 16 is located at the F position or the R position, for example, the target revolution speed of the prime mover 4 ranging from 1300 to 1900 rpm is provided in response to the accelerator pedal 1. Therefore, when the hydraulic system is driven at the time of non-traveling, it is possible to stably operate the prime mover, and to achieve the maximum flow of the hydraulic pump, so that the working speed can be adjusted over a wide range. At the time of traveling, the responsiveness at the time of pressing down the accelerator pedal is improved, which makes it possible to achieve the excellent acceleration. Moreover, even at the time of traveling during which the shift lever 16 is located at the F or R position, the target revolution speed of the prime mover 4 becomes the minimum revolution speed at the time of not operating the accelerator pedal 1. Accordingly, it is possible to improve the fuel efficiency.

A second embodiment of the present invention will be described with reference to Figs. 17 through 19. According to this embodiment, instead of determining the motor acceleration torque from the accelerator operation amount, a

limit ratio of the motor torque is determined.

Fig. 17 is a functional block diagram that is similar to Fig. 2, the functional block diagram illustrating processing steps of a drive system according to this embodiment. Fig. 18 is a flowchart illustrating the processing steps, the flowchart corresponding to Fig. 4 according to the first embodiment.

In this embodiment, processing steps of the control on the prime mover side (processing steps in the steps 101 through 106 shown in Fig. 3), and processing steps before the maximum motor torque T_{max1} is calculated on the electric motor side (processing steps from the step 111 shown in Fig. 3 up to the step 122 shown in Fig. 4), are the same as those in the first embodiment. In this embodiment, in a step 122, the maximum motor torque T_{rmax1} is calculated from the rotational speed ω_R , ω_L of the electric motors 12R, 12L and the function $T_{rmax1}(\omega)$ of the maximum motor torque. After that, in a step 131, a motor torque limit ratio K_{max} corresponding to the operation amount of the accelerator pedal 1 is calculated with reference to a data map showing the relationship between the accelerator operation amount and the motor torque limit ratio, the data map being expressed by a function $K_{max}(p)$ of the motor torque limit ratio shown in Fig. 19 (block 225A in Fig. 17).

In Fig. 19, the function $K_{max}(p)$ is made by assigning a limit ratio (in percent) to the vertical axis of the function of the motor acceleration torque shown in Fig. 15, and by replacing a numerical value of the limit ratio with a

ratio (%) to the maximum allowable motor torque Tr_{max} .

In a step 132, the maximum motor torque Tr_{max1} is multiplied by the motor torque limit ratio K_{max} , which has been determined in the step 131, to calculate the maximum motor torque Tr_{max2} (blocks 231, 232 shown in Fig. 17).

In a step 133, the target motor torque Tr_{1R} , Tr_{1L} is compared with the maximum motor torque Tr_{max2} , which has been determined in the step 132, to select the minimum value between them so that the selected values are used as motor torque instructed values Tr_R , Tr_L respectively (blocks 233, 234 shown in Fig. 17).

To be more specific,

$$Tr_R = \min(Tr_{1R}, Tr_{max2})$$

$$Tr_L = \min(Tr_{1L}, Tr_{max2})$$

The subsequent steps 125, 126 are the same as those described in the first embodiment in Fig. 4. The target engine revolution speed N_r is transmitted to the electronic governor 4a of the prime mover 4 as an instruction, and the motor torque instruction values Tr_R , Tr_L are transmitted to the inverters 73R, 73L as instructions.

In the above description, as is the case with the processing performed in the step 123 (the block 225) in the first embodiment, the processing performed in the steps 131, 132 (the blocks 225A, 231, 232) form acceleration torque limit value calculation means for calculating acceleration torque limit values (the maximum motor torque Tr_{max2}) of the electric motors 12R, 12L corresponding to the operation

amount of the accelerator pedal 1. As is the case with the processing performed in the step 124 (the blocks 226, 227) in the first embodiment, the processing performed in the step 133 (the blocks 233, 234) forms motor torque instruction value determination means for, when the acceleration torque limit value (the maximum motor torque Tr_{max2}) is larger than the target motor torque Tr_{lR} , Tr_{lL} , selecting the target motor torque as motor torque instruction values Tr_R , Tr_L , and for, if the acceleration torque limit value (the maximum motor torque Tr_{max2}) becomes smaller than the target motor torque Tr_{lR} , Tr_{lL} , selecting acceleration torque limit values (the maximum motor torque Tr_{max2}) as the motor torque instruction values Tr_R , Tr_L .

As described above, also in this embodiment, processing functions, which are included in the steps 131, 132 (the blocks 225A, 231, 232) and in the step 133 (the blocks 233, 234), are the same as those included in the step 123 (the block 225) and in the step 124 (the blocks 226, 227) in the first embodiment. Therefore, it is possible to achieve excellent operational feeling in which the operation amount of the accelerator pedal is well balanced with the output horsepower of the electric motors. It is also possible to achieve excellent controllability at the time of very slow traveling, and to easily make a delicate positioning.

Up to this point, the embodiments of the present invention have been described. However, the present invention can be changed in various ways within the spirit

and scope of the present invention. Some examples thereof will be described as below.

For example, in the embodiment described above, in the step 111 (the block 211), on the basis of the actual revolution speed N_e of the prime mover 4, the corresponding available maximum horsepower M_r for the electric motors 12R, 12L is determined with reference to the function $M_r(N_e)$ of the maximum motor output horsepower. However, usually the accelerator pedal is not rapidly operated, and accordingly the actual revolution speed N_e of the prime mover 4 is substantially equivalent to the target revolution speed N_r . Therefore, instead of using the actual revolution speed N_e of the prime mover 4, the target revolution speed N_r may also be used to determine the available maximum horsepower M_r for the electric motors 12R, 12L. In addition, the output horsepower upper limit P_{max} per one electric motor 12R or 12L is calculated with the maximum horsepower M_r being halved ($1/2$). However, in the step 118 (the block 217), after selecting the smaller value between the motor output horsepower upper limit P_{max} and the target motor output horsepower P_{m0} , the smaller value in question may also be halved ($1/2$) so that the halved value is used as the target motor output horsepower P_m .

Moreover, although the electric motors 12R, 12L are induction motors, they may also be synchronous motors.

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The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that
5 that prior publication (or information derived from it) or known matter forms part of the common general knowledge.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and
10 "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A drive system for an electrically driven dump truck comprising:

5 a prime mover;

an electronic governor for controlling the revolution speed and torque of the prime mover;

an alternating-current generator driven by the prime mover;

10 a hydraulic pump for working driven by the prime mover;

at least two electric motors for traveling, each of which is driven by the electric power supplied by the alternating-current generator; and

15 at least two inverters, each of which is connected to the alternating-current generator, and each of which controls each of the electric motors,

wherein the drive system comprises:

an accelerator pedal;

20 a shift lever that is operated at one of a plurality of positions including a neutral position and a forward position;

motor control means, for controlling the inverters to control the electric motors in response to the operation

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amount of the accelerator pedal; and

prime mover control means for, when the shift lever is located at the neutral position, calculating a target revolution speed corresponding to the operation amount of the accelerator pedal on the basis of first target revolution speed characteristics which are suitable for driving of the hydraulic pump for working to control the electronic governor on the basis of the target revolution, and for, when the shift lever is located at the forward position, calculating a target revolution speed corresponding to the operation amount of the accelerator pedal on the basis of second target revolution speed characteristics which are suitable for driving of the electric motors to control the electronic governor on the basis of the target revolution speed.

2. The drive system for the electrically driven dump truck according to Claim 1, wherein:

the first target revolution speed characteristics are set so that when the operation amount of the accelerator pedal is at 0, the target revolution speed is the minimum revolution speed, and so that with the increase in the operation amount of the accelerator pedal, the target revolution speed increases from the minimum revolution speed up to the maximum revolution speed; and

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the second target revolution speed characteristics are set so that when the operation amount of the accelerator pedal is at 0 or the predetermined very small operation amount, the target revolution speed is a medium-speed
5 revolution speed which is higher than the minimum revolution speed and lower than the maximum revolution speed, and so that with the increase in the operation amount of the accelerator pedal, the target revolution speed increases from the medium-speed revolution speed up
10 to a high-speed revolution speed.

3. The drive system for the electrically driven dump truck according to Claim 2, wherein:

the second target revolution speed characteristics are set so that when the operation amount of the accelerator
15 pedal falls within a range from 0 to the very small operation amount, the target revolution speed is the minimum revolution speed, and so that when the operation amount of the accelerator pedal reaches the very small operation amount, the target revolution speed increases up
20 to the medium-speed revolution speed step by step.

4. The drive system for the electrically driven dump truck according to Claim 2 or 3, wherein:

the minimum revolution speed is a revolution speed ranging from 700 rpm to 800 rpm;

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the medium-speed revolution speed is a revolution speed ranging from 900 rpm to 1600 rpm; and

the maximum revolution speed and the high-speed revolution speed are a revolution speed ranging from 1800
5 rpm to 2100 rpm.

5. The drive system for the electrically driven dump truck according to Claim 2 or 3, wherein:

the predetermined very small operation amount of the accelerator pedal is a operation amount ranging from 2 to
10 8% of the maximum operation amount of the accelerator pedal.

6. The drive system for the electrically driven dump truck according to Claim 1, wherein:

the prime mover control means includes:

15 first target revolution speed calculation means for calculating a first target revolution speed corresponding to the operation amount of the accelerator pedal on the basis of the first target revolution speed characteristics;

20 second target revolution speed calculation means for calculating a second target revolution speed corresponding to the operation amount of the accelerator pedal on the basis of the second target revolution speed characteristics; and

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target revolution speed determination means for,
when the shift lever is located at the neutral position,
selecting the first target revolution speed calculated by
the first target revolution speed calculation means, and
5 for, when the shift lever is located at the forward
position, selecting the second target revolution speed
calculated by the second target revolution speed
calculation means.

7. The drive system for the electrically driven dump
10 truck according to Claim 1, wherein:

the motor control means includes:

target motor output horsepower calculation means
for calculating a first target motor output horsepower
corresponding to the operation amount of the accelerator
15 pedal;

target motor torque calculation means for
calculating a target motor torque on the basis of the first
target motor output horsepower and a rotational speed of
the two electric motors;

20 acceleration torque limit value calculation means
for calculating an acceleration torque limit value of the
two electric motors corresponding to the operation amount
of the accelerator pedal;

motor torque limiting means for limiting the

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target motor torque so that the target motor torque does not exceed the acceleration torque limit value; and

inverter control means for controlling the inverters on the basis of the target motor torque that is
5 limited by the acceleration torque limit value.

8. A drive system, substantially as hereinbefore described with reference to the accompanying drawings.

FIG. 1

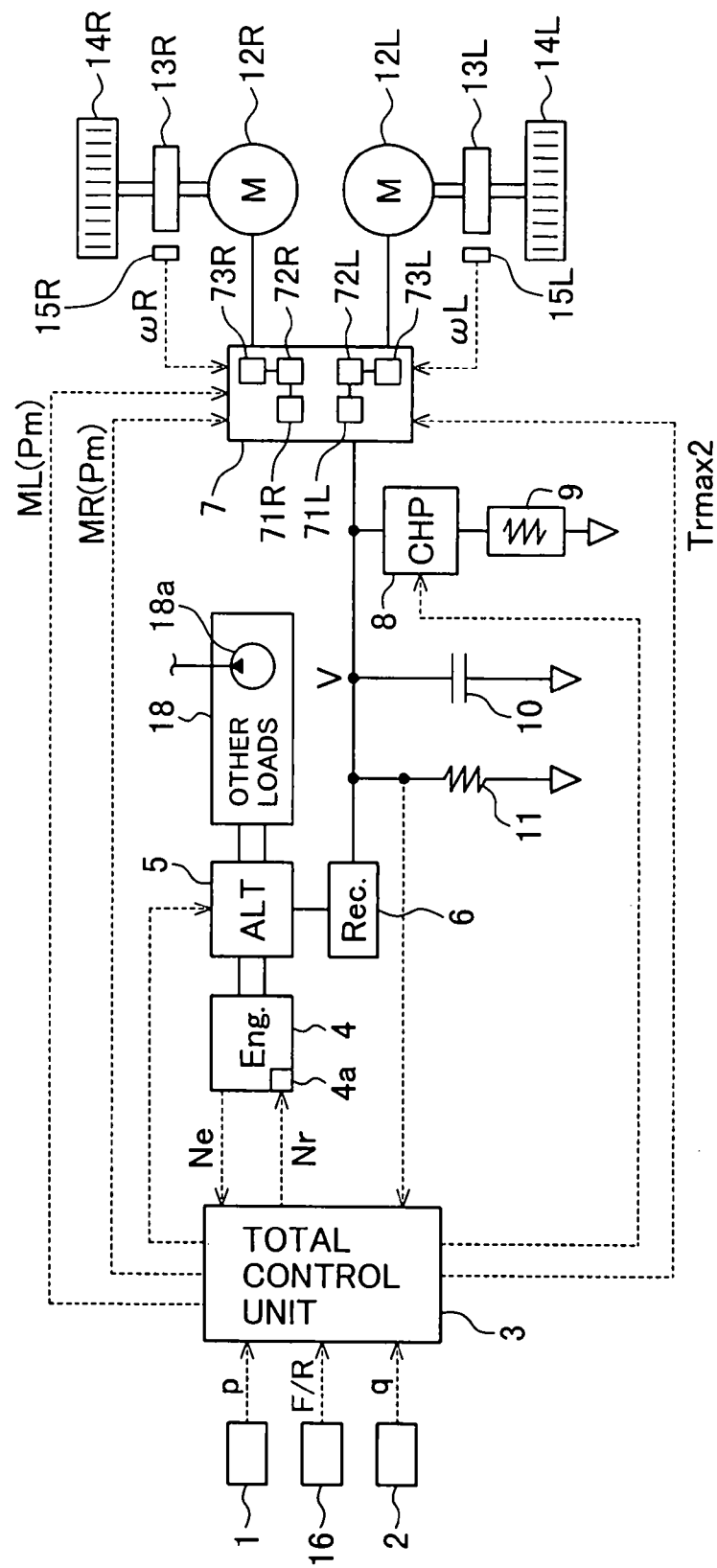


FIG. 2

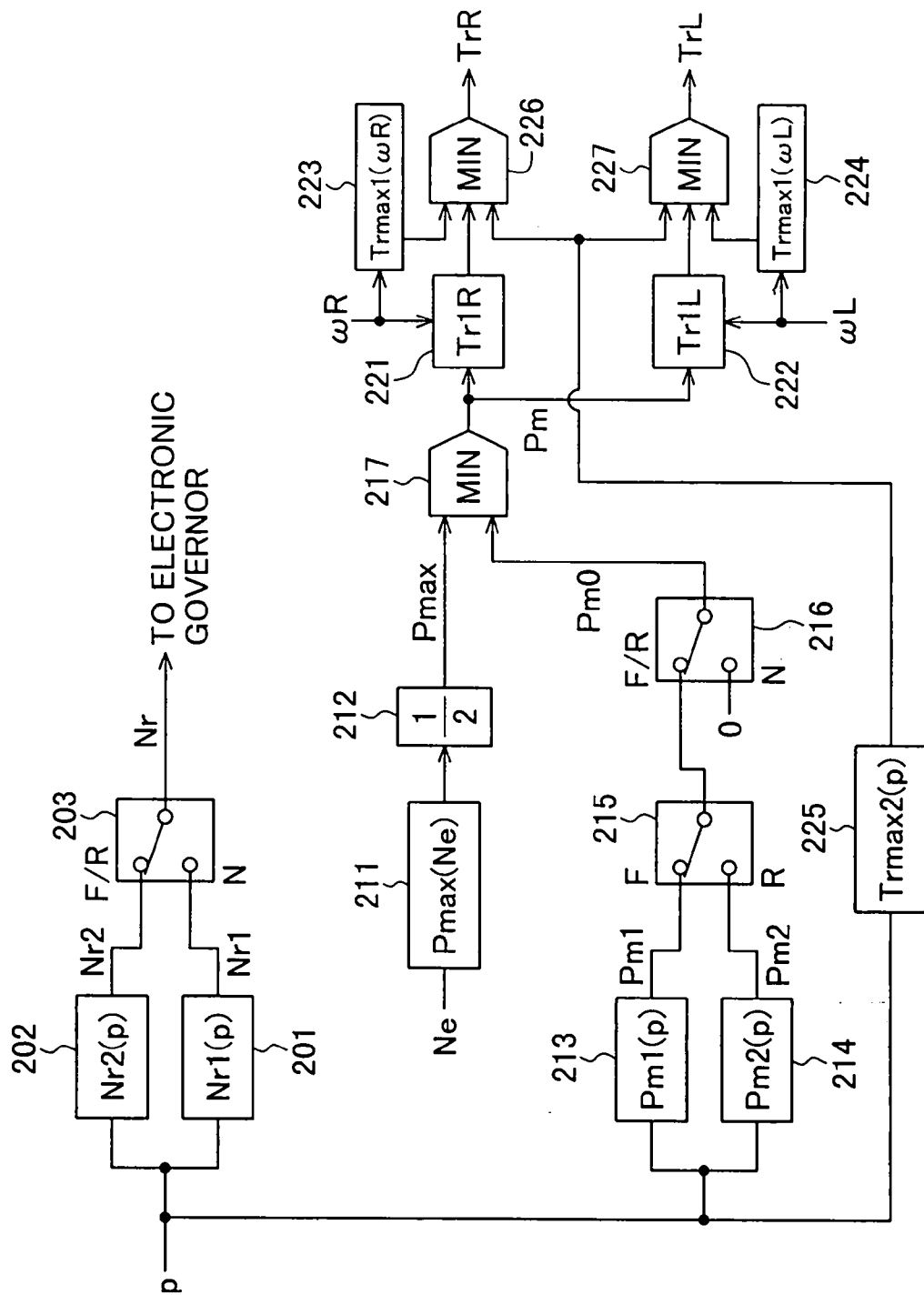


FIG.3

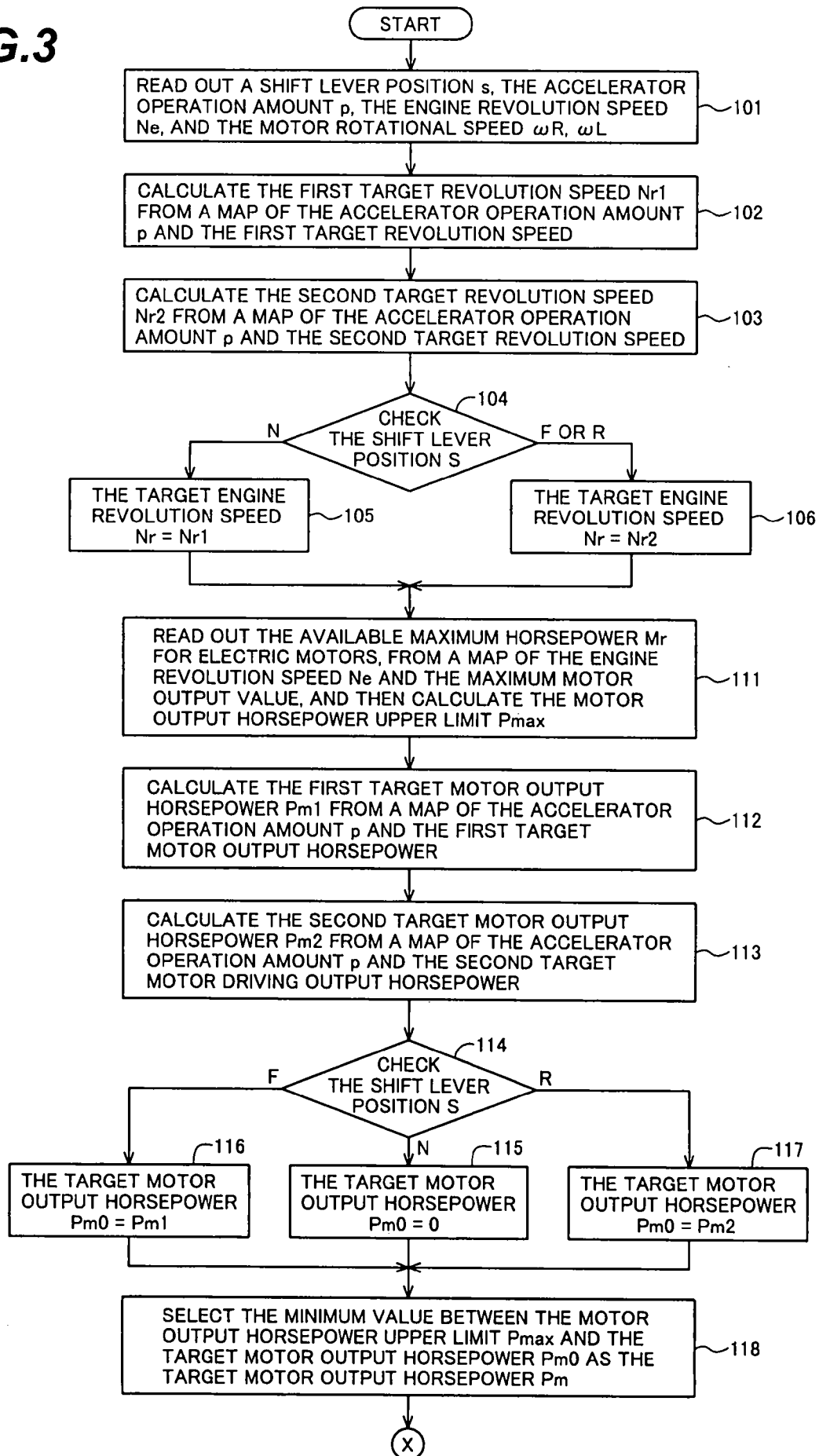


FIG.4

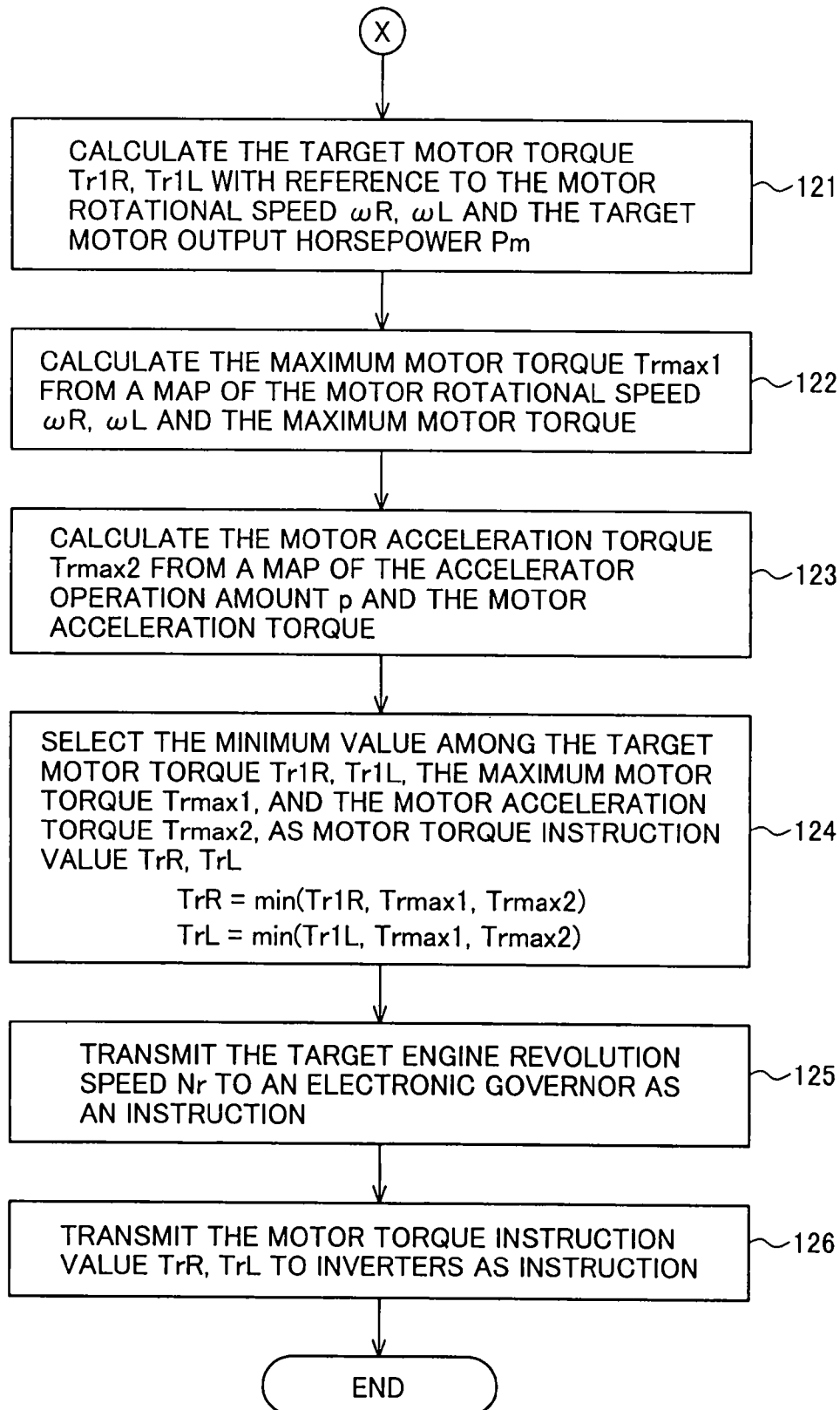


FIG.5

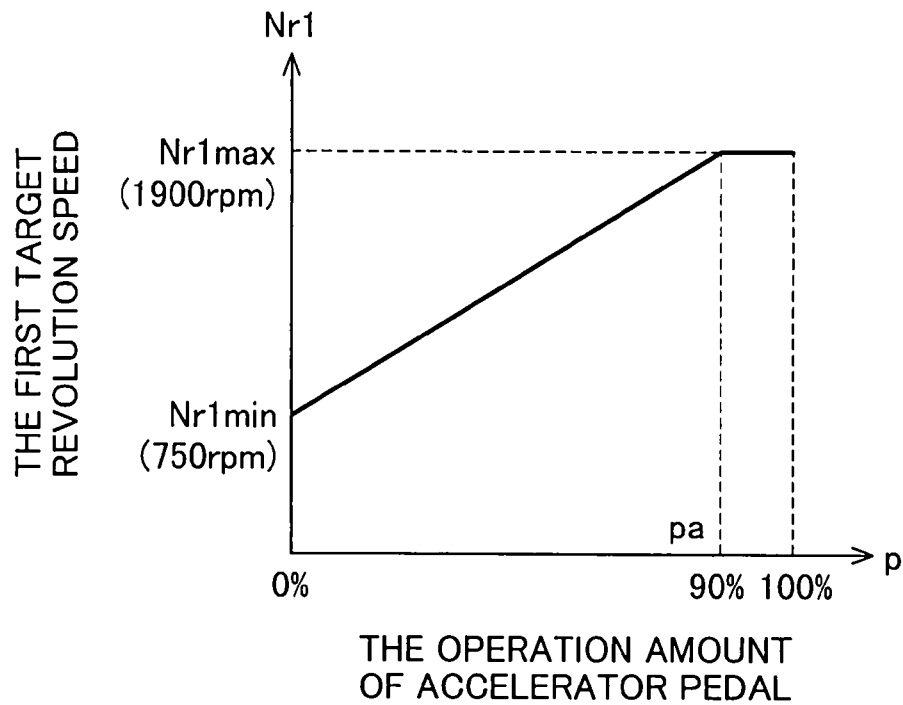


FIG.6

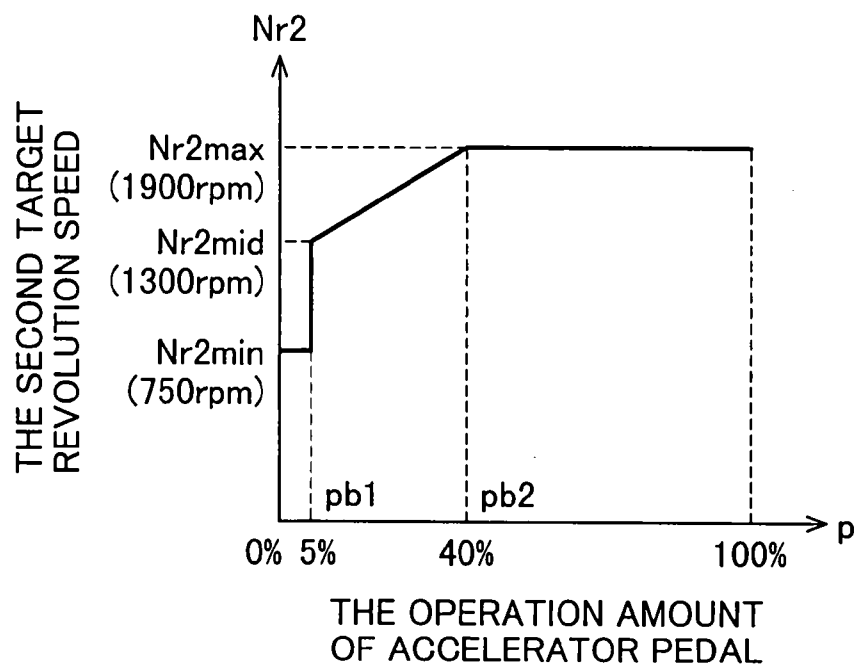


FIG.7

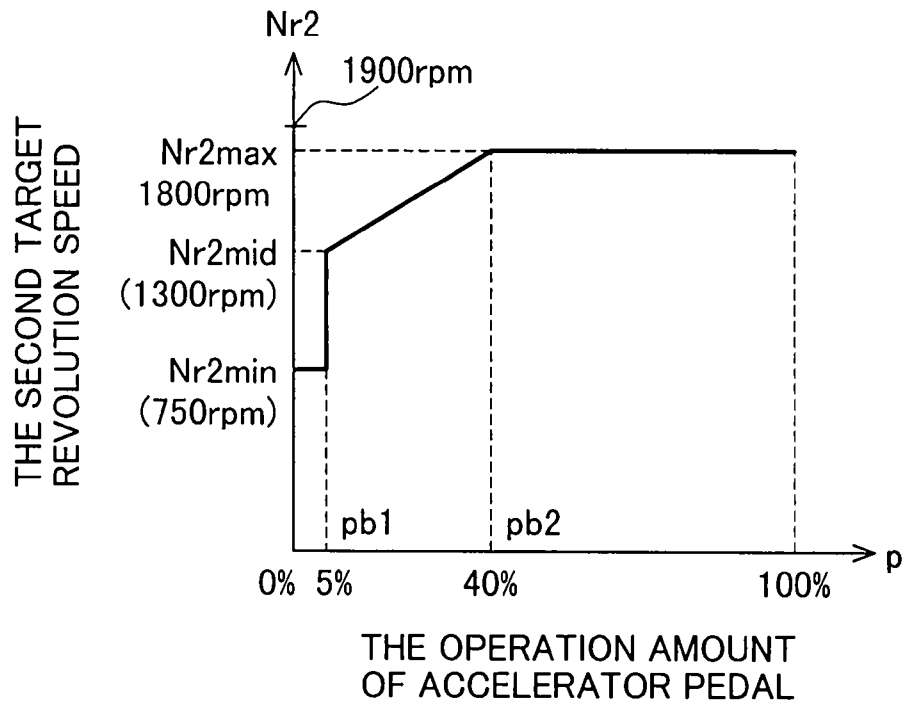


FIG.8

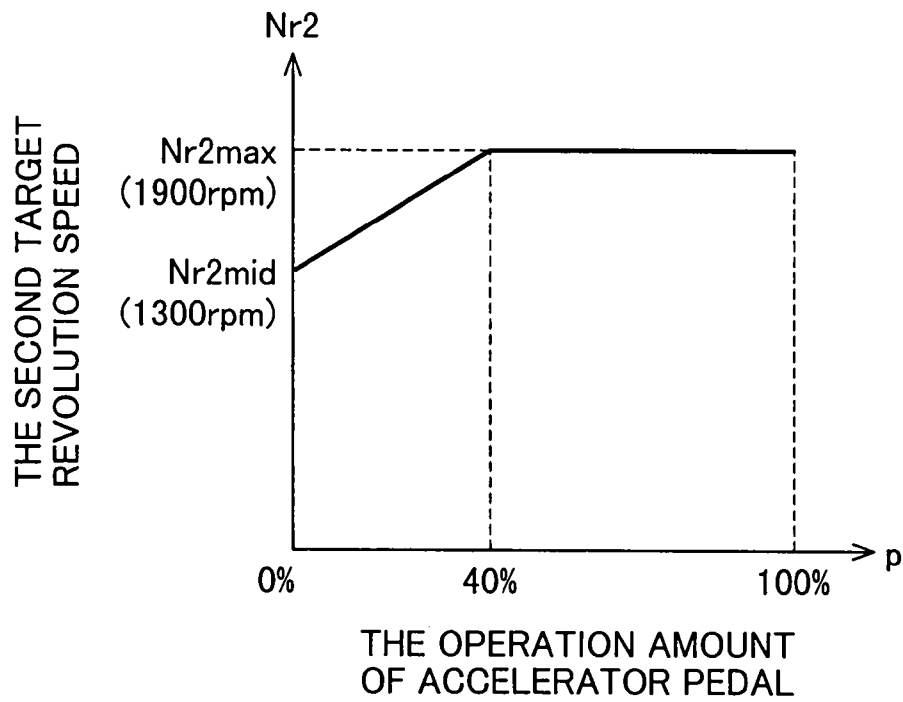


FIG.9

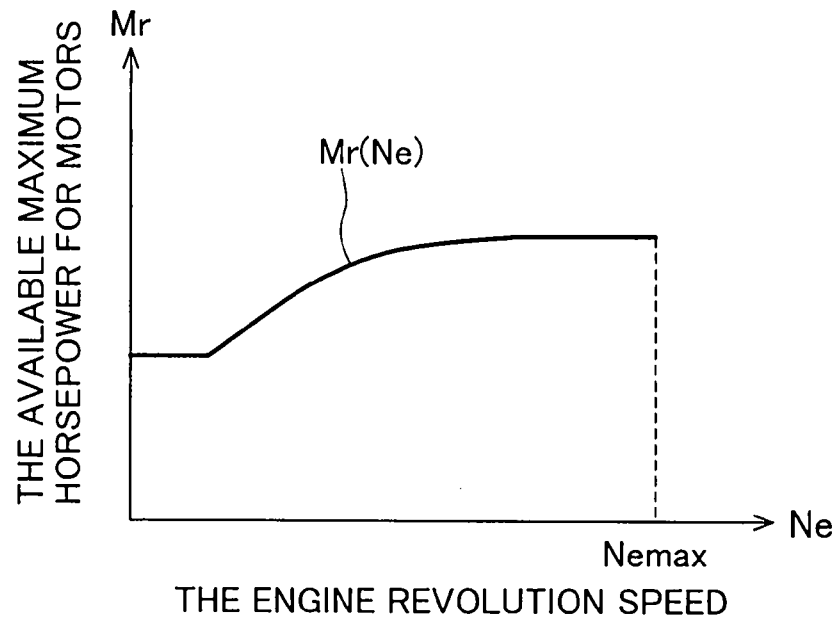


FIG.10

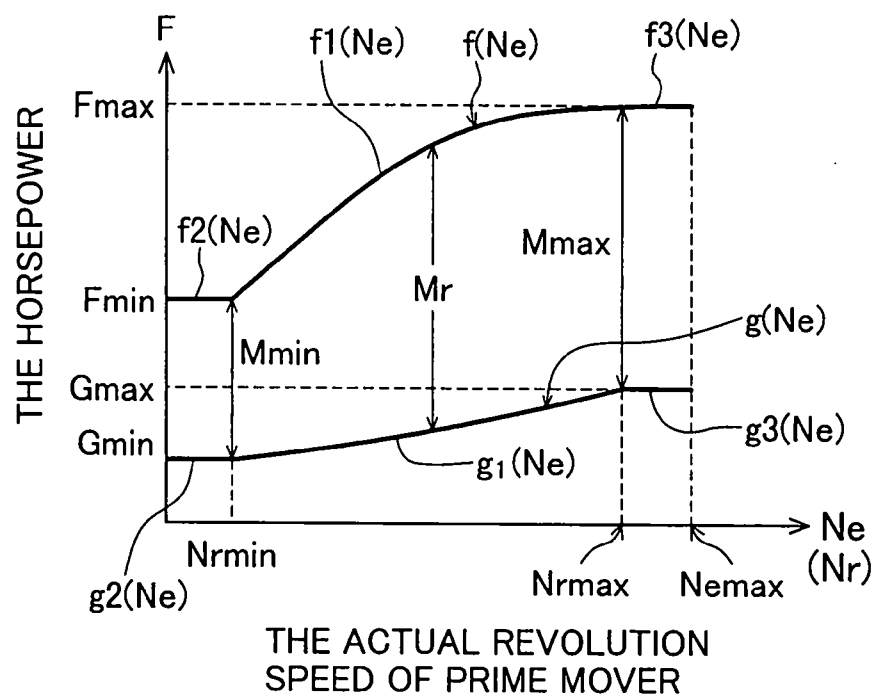


FIG.11

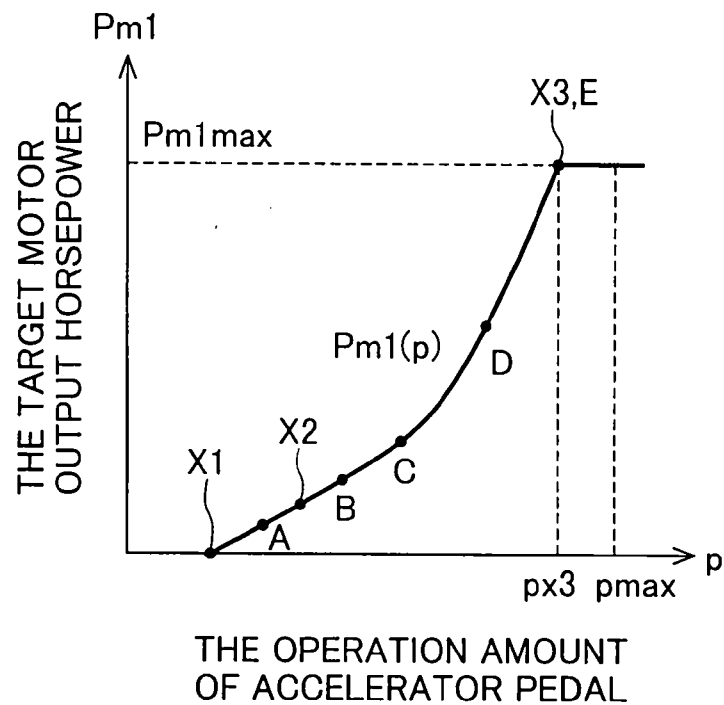


FIG.12

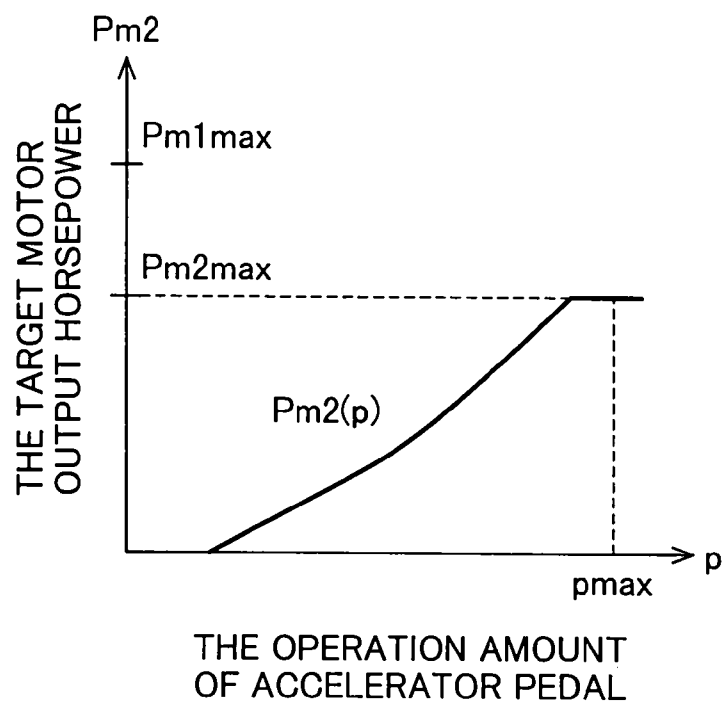


FIG.13

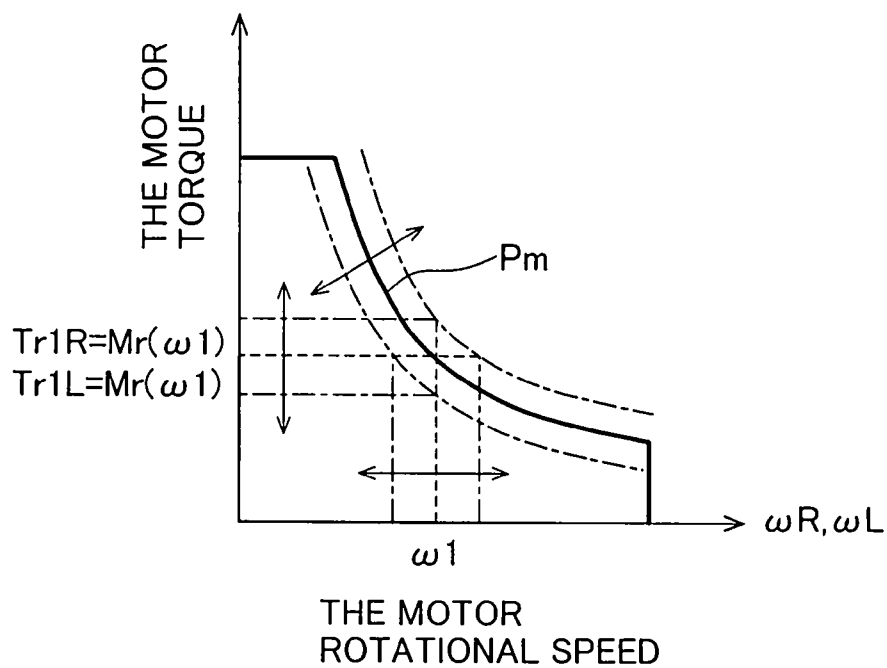


FIG.14

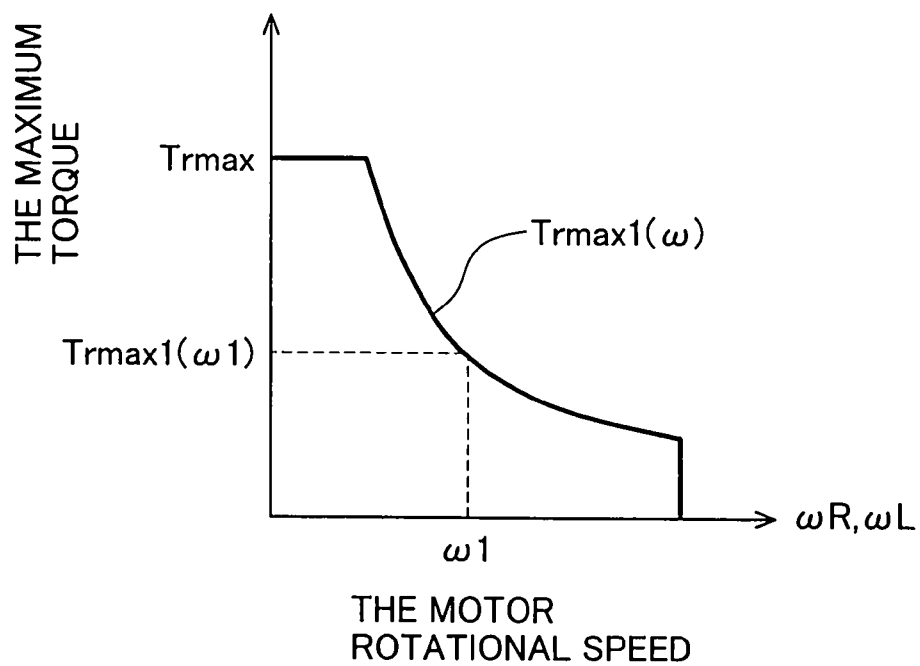


FIG.15

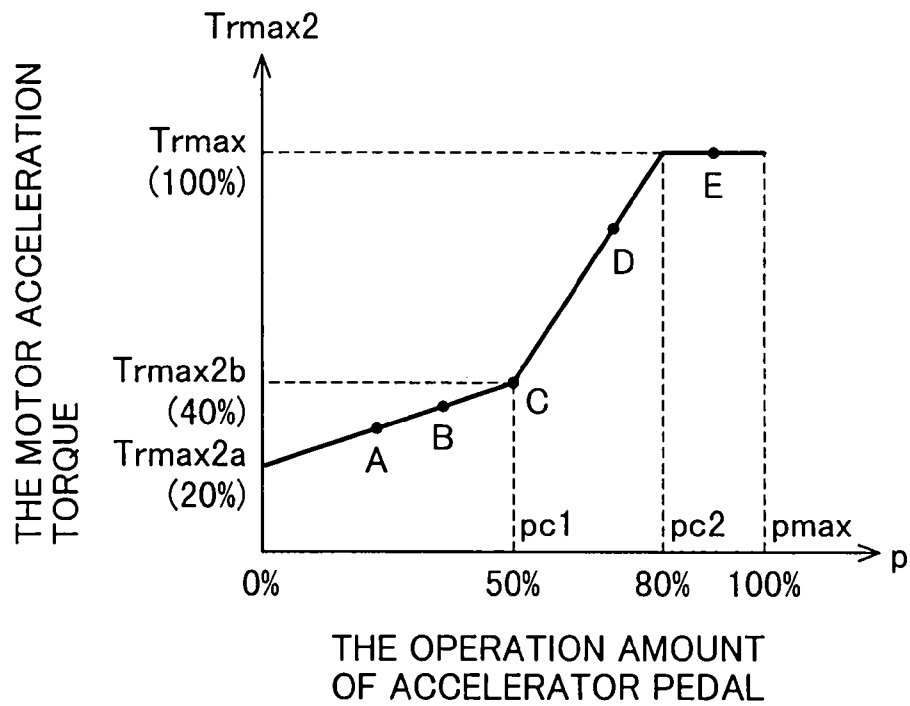


FIG.16

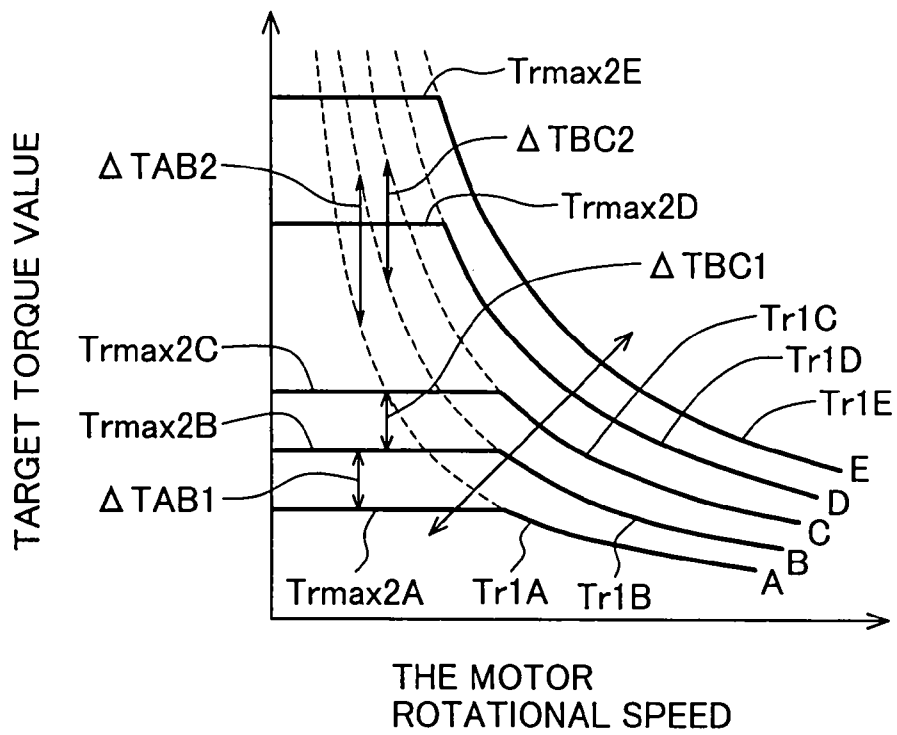


FIG.17

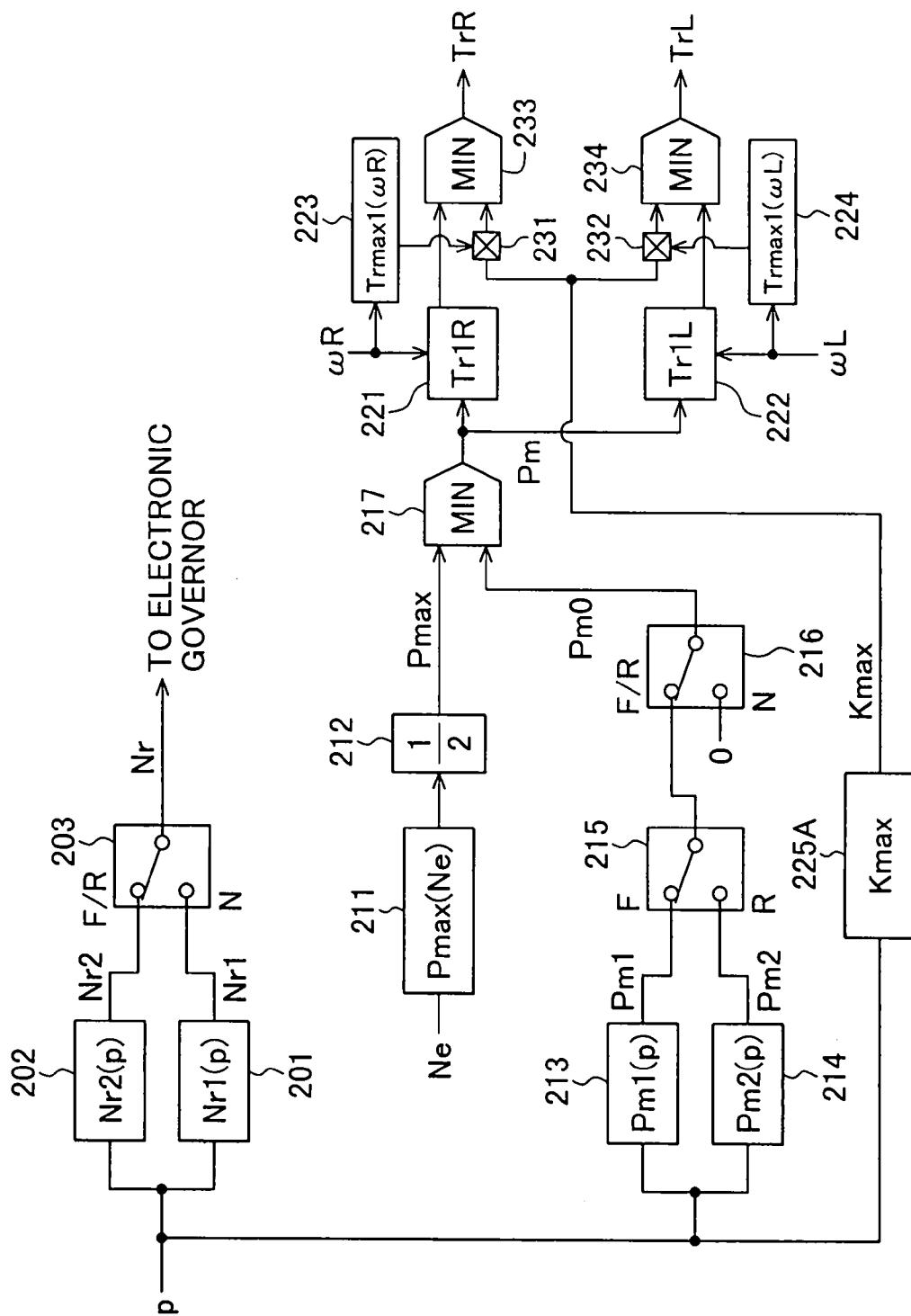


FIG.18

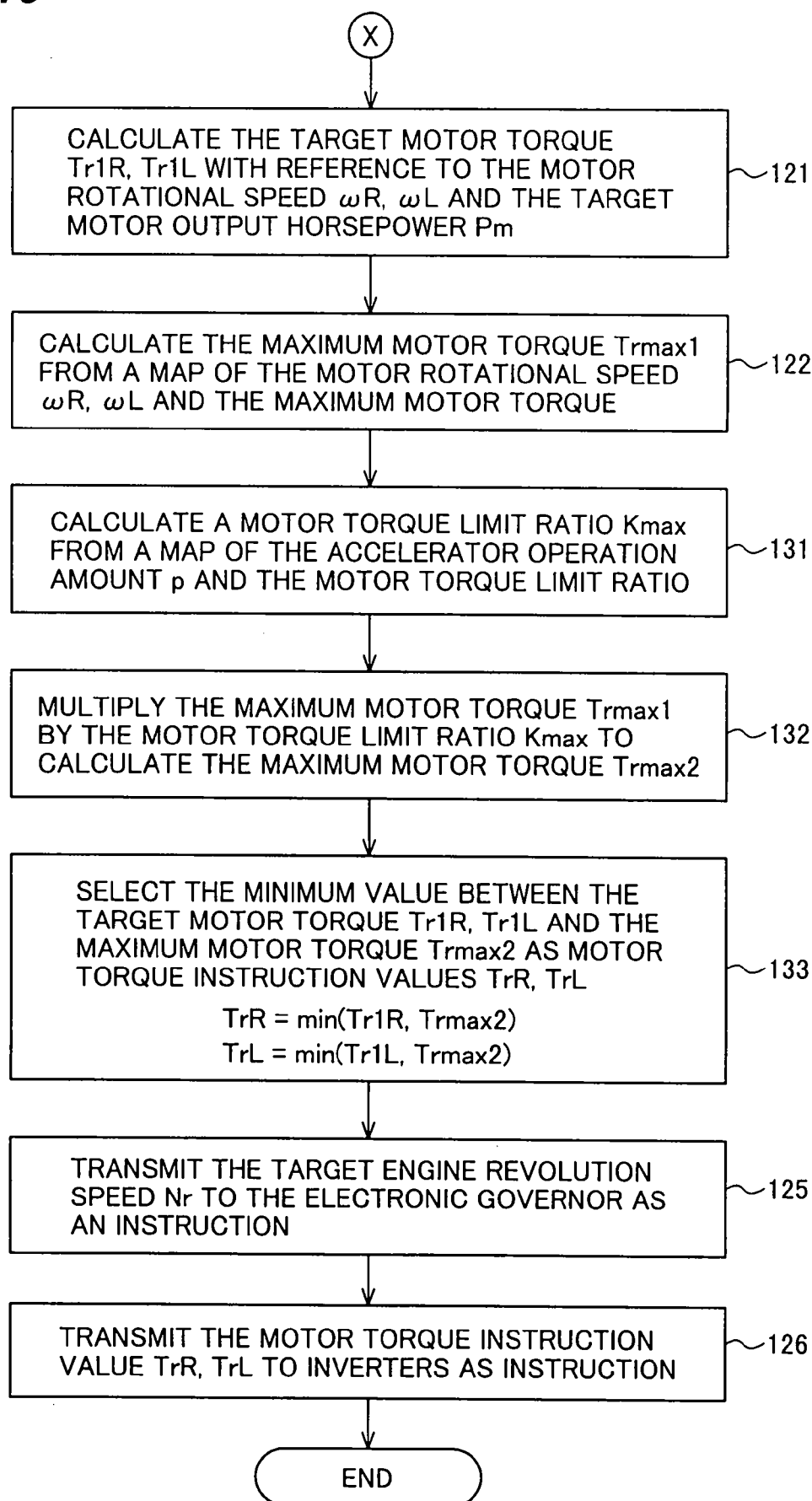


FIG.19

