United States Patent [19]

Aihara et al.

[11] **3,865,209**

[45] **Feb. 11, 1975**

[54] **ELECTRICALLY DRIVEN INDUSTRIAL VEHICLES**

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[22] Filed: **July 2, 1973**

[21] Appl. No.: **375,797**

[30] **Foreign Application Priority Data**

July 28, 1972 Japan.................................. 47-88306

[52] **U.S. Cl.**.................... **180/65 R,** 310/83, 318/12

[51] **Int. Cl.**........................... **B60l 15/06,** B60l 9/16

[58] **Field of Search**........ 180/2, 65 R; 310/83, 129, 310/160, 166; 321/64; 318/11, 12

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[57] **ABSTRACT**

An electrically driven vehicle employs an induction motor as a drive train motor with a gear matching transmission connecting it with the drive train of the vehicle so the transmission matches its rotational speed to be compatible with the drive train arrangements of a conventionally-driven diesel engine drive train at several different frequencies of its alternating power source, which is supplied through a cable connecting the vehicle to a suitable power source. In addition, the induction drive motor may be configured for four- or six-pole operation, whereby switching therebetween will provide a dual operating speed range for the motor at any single frequency of the power source, giving the machine additional flexibility.

2 Claims, 6 Drawing Figures

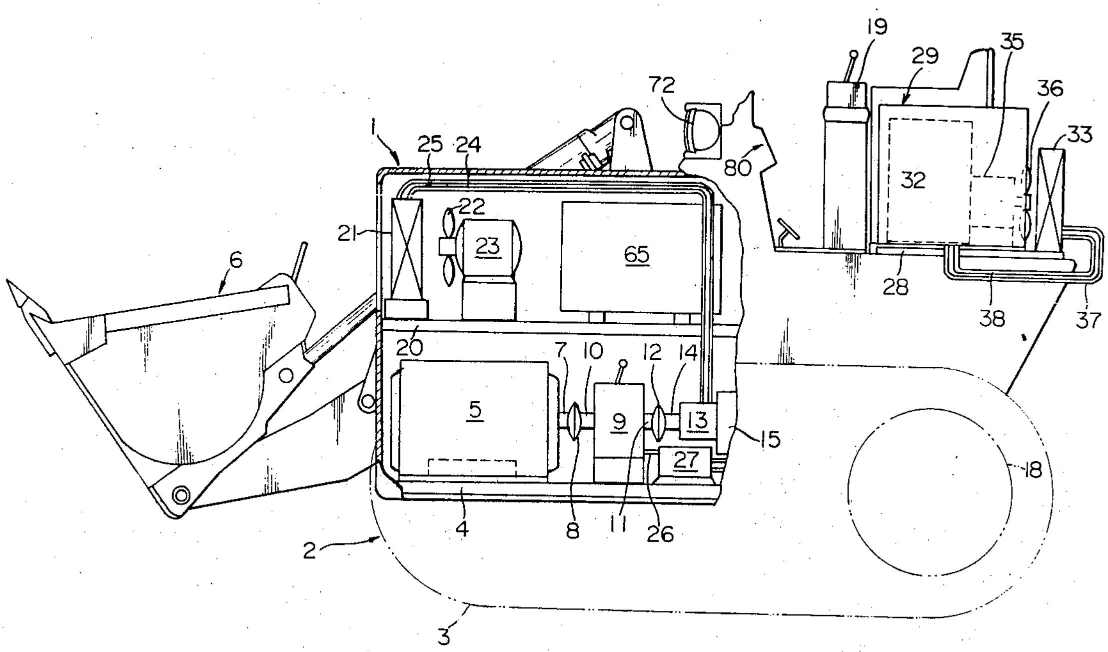

Fig. 1

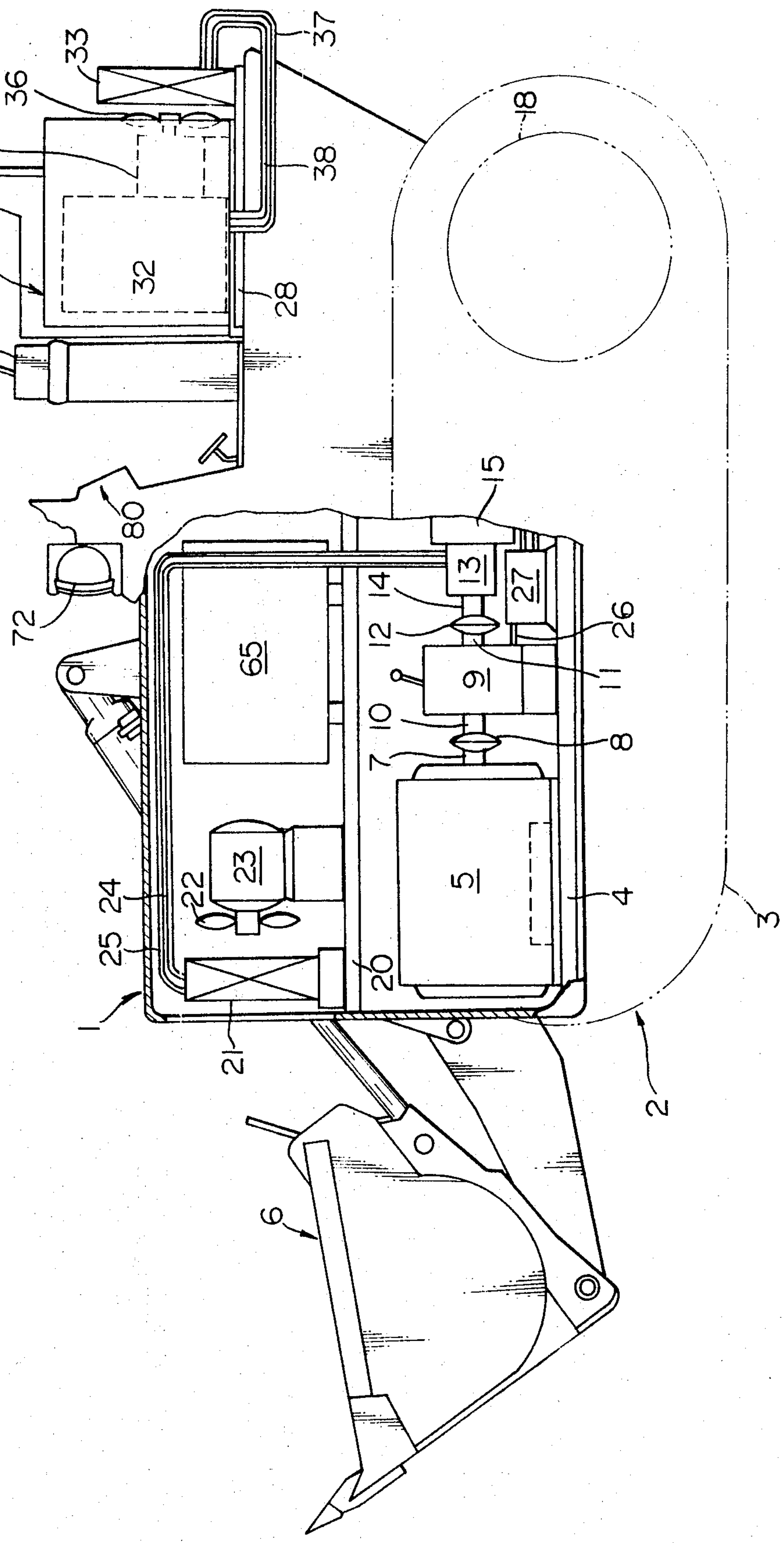
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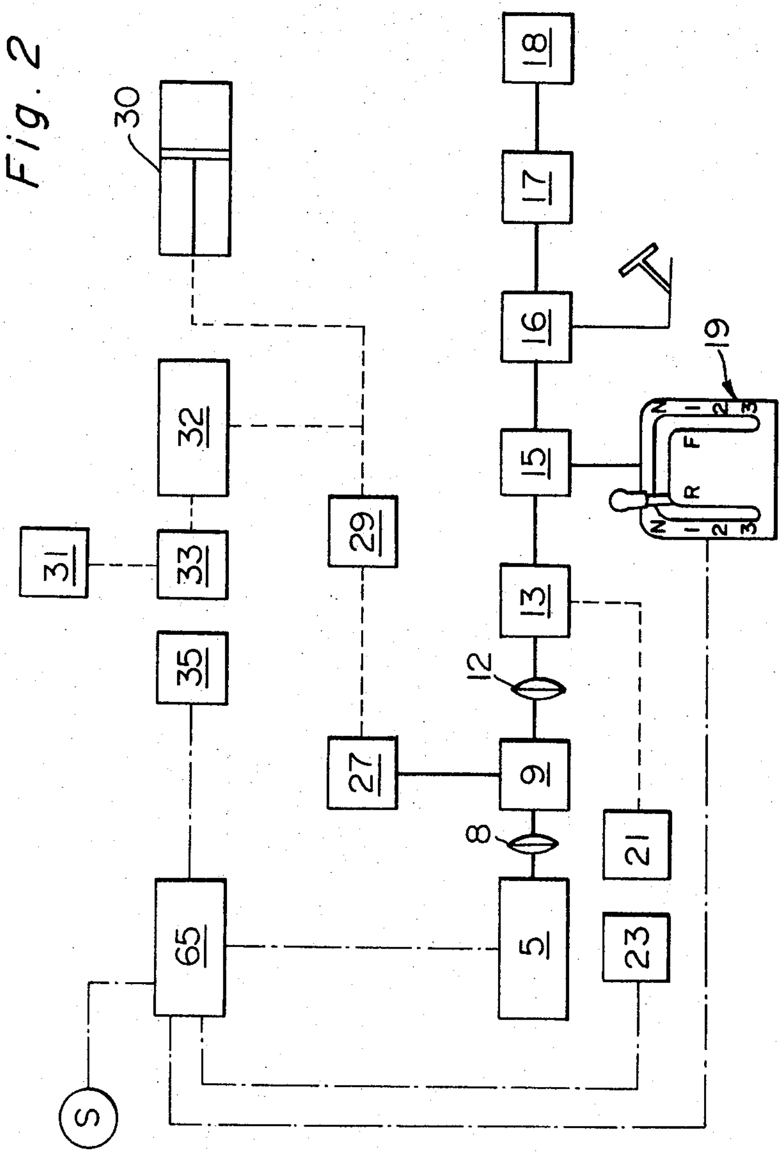
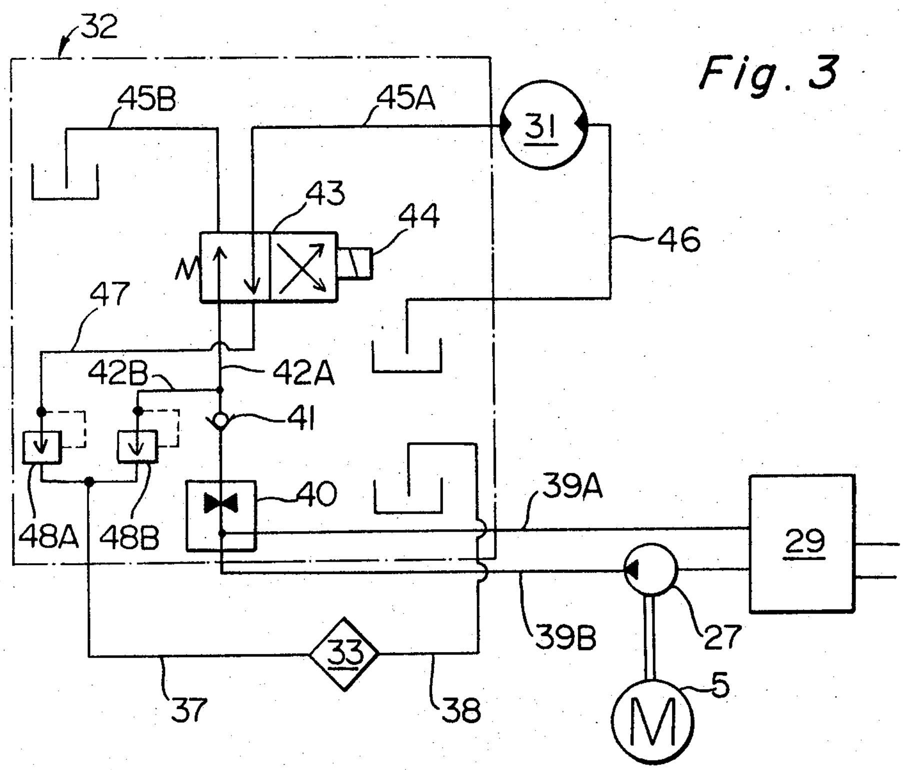
Fig. 2

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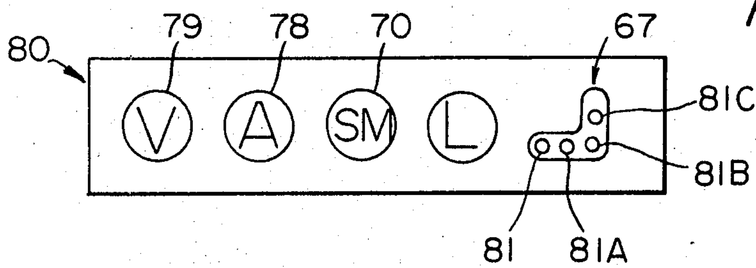
M

Fig. 3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81C
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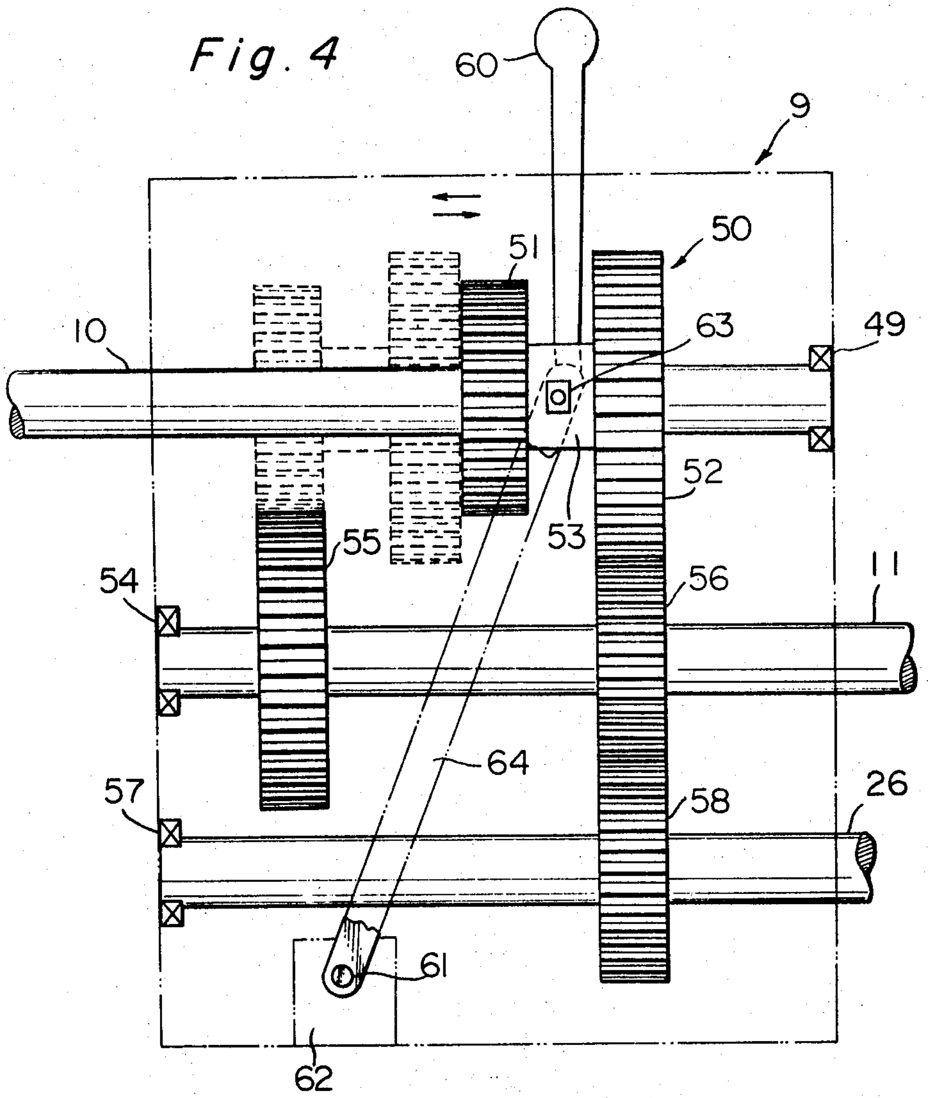
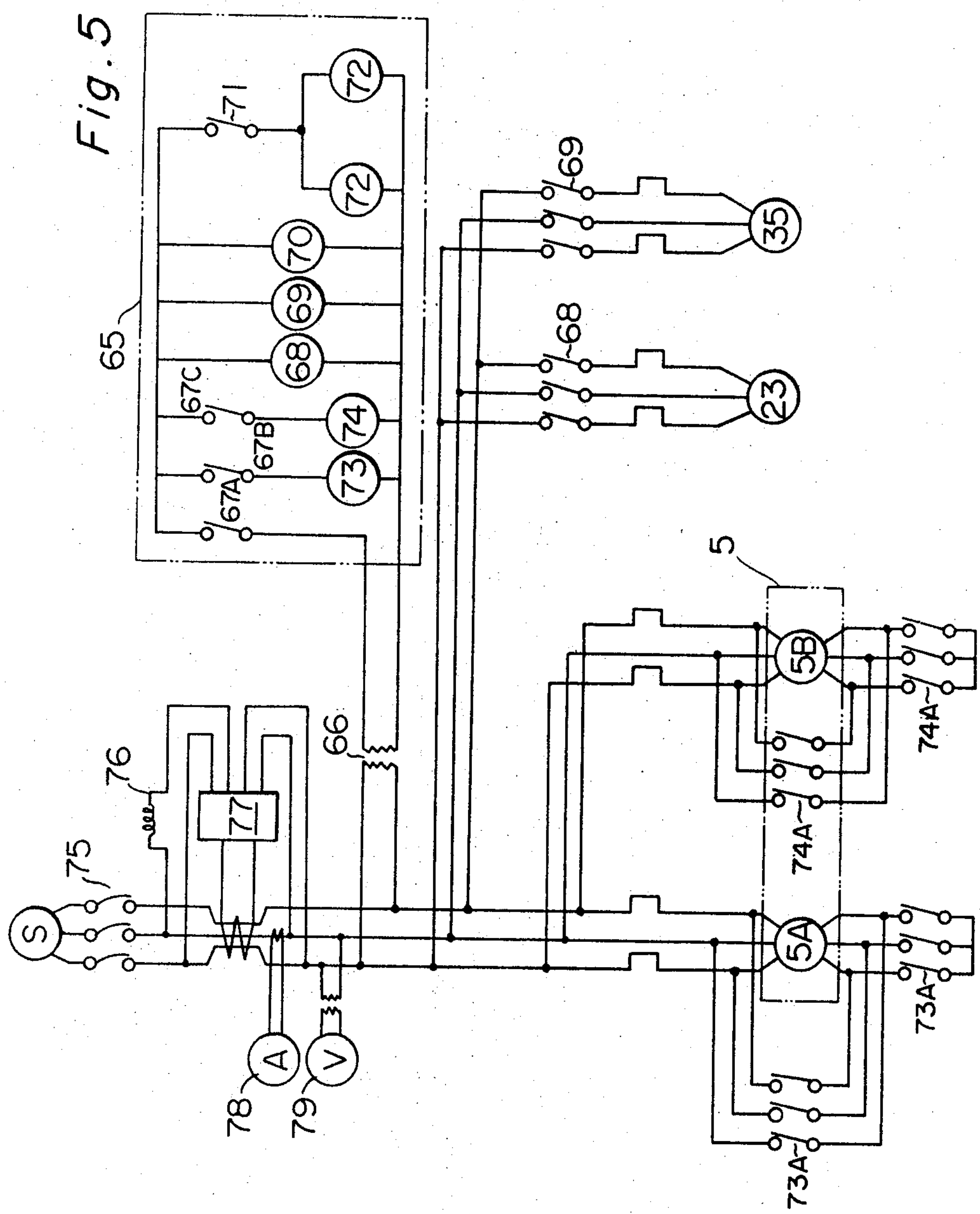
81A

Fig. 6

Fig. 4

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66
75
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73A
A
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Fig. 5

ELECTRICALLY DRIVEN INDUSTRIAL VEHICLES

BACKGROUND OF THE INVENTION

When a vehicle is powered by an induction motor connected to a source of alternating current, the speed of the induction motor will be dependent upon the frequency of the alternating current source. Thus, it is desirable to have an arrangement whereby the operation of the vehicle powered in this manner may be reasonably constant when the alternating current source has one of several standardized frequencies.

In the past, vehicles such as track-type or wheel-type tractor loaders or tractors used in construction or earth-moving operations have been generally powered by diesel engines. As a result, these machines are noisy and generate exhaust gases which are frequently regulated by anti-pollution laws. Further, a substantial portion of the noises which are ascribed to these machines result from the combustion occurring within the engine along with the operation of the auxiliary equipment such as the radiator fan. Thus, there has been a desire to reduce the noise level of such vehicles and also to eliminate the noxious ingredients of the exhaust gases from the diesels, which are generally CO_2, CO, hydrocarbons and nitrogen oxides, which pose extreme difficulties in confined spaces such as tunnels and the like, where these gases can be lethal to human life.

To avoid some of the problems noted above, vehicles of this type have been provided with electric drive systems. Normally, in confined locations such as tunnels, power to the electrically driven drive can be supplied by cables connecting the vehicle to a suitable power source. While the electric drive will reduce the noise problems to some extent and also reduces the noxious exhaust gases, other problems are often experienced with such drive systems.

One of the problems is that the rotating speed of an induction motor is determined by the frequency of the alternating current supplied to it. Further, the current designs of induction motors or machines are not generally compatible with the operating speeds of an ordinary diesel engine at the conventional 50 and 60 cycle frequencies of alternating current sources. As a result, an induction motor cannot be substituted for a diesel engine in a conventional vehicle without adversely affecting the operation of the vehicle or completely redesigning the drive train thereof. The vehicle will generally lose tractive effort and have increased work cycle time on any given job, reducing the overall operating efficiency.

As indicated, the total drive train design of the vehicle can be changed to be compatible with the electric drive system, but such a redesign is somewhat costly.

Furthermore, even if such a design change in the drive train was effected, the frequency of alternating sources which would be utilized to supply power to the induction motor of the vehicle varys from country to country, and in certain countries, from area to area within that country. Thus, if the vehicle is designed for a particular frequency, it would only be compatible with power sources having the frequency required by its design. Otherwise, the overall operation of the vehicle would not be efficient unless a power source having the proper frequency is available.

Furthermore, if the induction motor operating the drive train operates the auxiliary equipment of the machine such as the hydraulic pumps and the like, these hydraulic circuits will also be adversely affected if the improper frequency is utilized to power the vehicle.

It is appreciated that a brush-type electric motor might be employed as an alternative to the induction motor, and a heavy-duty rectifier employed between the motor and the alternating current source, so that the speed of the electric drive can be controlled continuously over a wide range of operating speeds. However, this type of arrangement has a much higher cost, and it requires considerably more maintenance than vehicles powered with inductions machines, the latter being the less complicated of the two systems. As a result, it is desirable to employ the less expensive, more reliable induction motor where possible in vehicle drives.

In view of the above, it is an object of the current invention to provide an electric drive for earthmoving vehicles employing an induction motor by equipping the vehicle with a transmission gear means between the induction motor and the drive system by which the input speed to the drive train can be maintained constant, even though the frequency of the alternating current source changes.

Another object of this invention is to provide an electric drive system for a conventional vehicle which has been designed for diesel engine drive without adversely affecting the machine operation.

Another object of the current invention is the provision of an electric drive for vehicles which employs an induction motor with several pole configurations so that it may be operated at two different speeds when connected to an alternating current source having a fixed frequency, thereby providing a low and high speed operating range.

Another object of this invention is connecting the hydraulic pump of the vehicle to the transmission gear means so that the rotating speed of the pump also will be essentially constant at different frequencies of the alternating current sources that might be utilized.

SUMMARY OF THE INVENTION

The above objects can be accomplished in a conventional industrial vehicle by providing it with a drive train which includes an induction motor as its drive motor, a transmission gear means connecting the induction motor to its conventional drive system operable to change the output speed of the induction motor to a speed compatible with that required by the drive train, and a hydraulic pump connected to the output of the transmission gear means whereby the hydraulic circuits of the vehicle likewise will be operated in an efficient manner. Also, the invention includes the utilization of an induction motor having several pole configurations so that it can be operated at at least two speeds from an AC power source having a constant fixed frequency.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is an elevation of an electrically driven vehicle in accordance with the present invention, having parts broken away to show additional internal detail;

FIG. 2 is a block diagram illustrating the drive system and a compatible hydraulic system for a vehicle configured with the electric drive as shown in FIG. 1;

FIG. 3 is a hydraulic schematic of the circuit for controlling a hydraulic winch motor which can be utilized to wind up or pay out an electric power supply cable by which the vehicle is connected to a suitable alternating power source;

FIG. 4 is an enlarged view of the matching gear transmission that is employed to match the output speed of the induction motor to the drive train of the electrically driven vehicle shown in FIG. 1;

FIG. 5 is an electrical schematic circuit of the vehicle shown in FIG. 1; and

FIG. 6 is a plan of the electrical control panel on the vehicle shown in FIG. 1.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to FIG. 1, a track-type earthmoving vehicle 1, such as a tractor loader, includes an undercarriage 2 including supporting endless tracks 3 on which the vehicle 1 moves in its longitudinal direction. An electric drive motor 5 is mounted on a main frame 4 of the undercarriage 2, and the tractor has a hydraulically operated bucket 6. In the embodiment shown in the drawings, a multiple pole induction motor 5 is employed that preferably has a 4-pole configuration and a 6-pole configuration. The employment of the several pole configuration induction motor is for the purpose of operating the vehicle safely and easily at either a low or high speed range. However, an induction motor having only a 4-pole configuration can be used. The induction motor 5 is powered by alternating current source supplied through a suitable electrical cable. The output of the motor is transmitted to the drive system of the vehicle 1 and also the hydraulic pump for operating the bucket 6.

The transmission of power from the drive motor 5 to the drive train system of the vehicle 1 will be briefly described in reference to FIGS. 1 and 2. An output shaft 7 of the motor 5 is connected to an input shaft 10 of a transmission gear means 9 through a flexible coupling 8. An output shaft 11 of the transmission gear means 9 is connected to an input shaft 14 of a torque converter 13 through a flexible coupling 12. As is shown in FIG. 2, the output of the torque converter 13 is serially connected to a transmission 15, a steering clutch 16, a final drive 17 and a sprocket 18. Each sprocket 18 drivingly engages an endless track 3. Accordingly, by operating a lever of a transmission shift means 19, the vehicle 1 can be moved longitudinally on the endless tracks 3. On a plate 20 disposed above the main frame 4, an oil cooling fan 22 is provided for cooling the oil for the torque converter 13. The oil for the torque converter 13 enters an oil cooler 21 through a pipe 24, is cooled there, and returns to the torque converter 13 through a pipe 25.

An auxiliary output shaft 26 of the transmission gear means 9 is connected to a hydraulic pump 27 that is driven by the drive motor 5 through the gear means 9. A hydraulic tank 29 which is mounted on a member 28 at the back of the vehicle 1 includes part of a hydraulic circuit (not shown) which controls a hydraulic cylinder which operates the bucket 6.

In the embodiment shown in the drawings, a hydraulic motor 31 is mounted at the back of the vehicle 1 which drives a device for winding or unwinding an electric power supply cable (not shown) according to the movement of the vehicle. This cable supplies alternating current to the drive motor 5 as well as other electrical devices on the vehicle. The details of the cable winding and unwinding device are disclosed in U.S. Pat. No. 3,632,906 to Aihara et al, which description is incorporated herein. The hydraulic motor 31 is controlled by a hydraulic circuit 32 and an oil cooler 33 and a cooling fan 36 driven by an electric motor 35 are mounted on the member 28 disposed at the rear of the vehicle 1. Oil from the hydraulic circuit 32 enters the oil cooler 33 through a pipe 37, is cooled there, and returns through a pipe 38. The drive motor 5 as well as electric motors 23 and 35 are controlled by a control circuit 65, as will be described below.

The hydraulic circuit 32 will be described in reference to FIG. 3. Oil from the hydraulic tank 29 is sent by rotation of hydraulic pump 27 to a flow divider 40 through a pipe 39A, and enters a change-over valve 43 through a check valve 41 and a pipe 42A. The change-over valve 43 includes a solenoid 44, which is electrically controlled. When the solenoid 44 is in the excited state, the oil that has entered the change-over valve 43 enters the hydraulic motor 31 through a pipe 45A to drive it and exhaust oil is drained through a pipe 46. When the solenoid is not in the excited state, the oil that has entered the change-over valve 43 is drained through a pipe 45B. Furthermore, in order to maintain the pressure constant, a relief valve 48B is provided in this hydraulic circuit 32 on pipe 42B branched from the pipe 42A which connects the change-over valve 43 and flow divider 40. A relief valve 48A is provided on a pipe 47 which leads to the change-over valve 43. Oil from the relief valve passes through the pipe 37, enters the oil cooler 35, is cooled there, and then drained through the pipe 38.

The excitation of the solenoid 44 can be controlled by a microswitch (not shown) which synchronizes with the operation of the lever of the transmission shift device 19.

The transmission gear means 9 will be described in detail in reference to FIG. 4. The transmission gear means 9 includes an input shaft 10 connected to the output shaft 7 of the drive motor 5 by the coupling 8, a first output shaft 11 connected to the input shaft 14 of the torque converter 13 of the drive system by means of coupling 12, and a second output shaft 26 connected to the hydraulic pump 27. The input shaft 10 is rotatably supported by a bearing 49. A spline is formed at the central part of the input shaft 10, and at this part, a gear member 50 consisting of a first gear 51, a second gear 52 and a connecting boss 53 is provided so that it is movable in the axial direction but is not rotatable relative to the input shaft 10. The first output shaft 11 is rotatably supported by a bearing 54 and has a third gear 55 and a fourth gear 56 secured thereto. The second output shaft 26 is rotatably supported by a bearing 57, and to this shaft is fixed a fifth gear 58 engaged with the fourth gear 56 secured to the first output shaft 11. The gear member 50 can move in the axial direction between a first position shown by the solid line and a second position shown by the broken line. At the first position, the second gear 52 comes into engagement with the fourth gear 56 fixed to the first output shaft 11, and at the second position, the first gear 51 comes into engagement with the third gear 55 fixed to the first output shaft 11. Accordingly, when the gear member 50 is situated at the first position, the rotation of the input shaft 10 is transmitted to the first output shaft 11 through the second and fourth gears. This rotation is then transmitted to the second output shaft 26 through the fourth and fifth gears. When the gear member 50 is located at the second position, the rotation of the input shaft **10** is transmitted to the first output shaft **11** through the first and third gears, and then to the second output shaft **26** through the fourth and fifth gears.

The gear member **50** further includes a lever **60** fixed to the boss **53**, and a rod **64** whose one end is pivotally connected at **61** to a base **62** of the transmission gear means **9** and whose other end is connected pivotally to a gear shifter **63** fitted slidably in a groove formed in the boss **53**. By operating the lever **60**, the gear member **50** is moved from the first position to the second or vice-versa.

When the frequency of alternating current to be supplied to motor **5** having four-pole configuration and also a six-pole configuration is 50 Hz or 60 Hz, the gear ratio is for example as follows:

Table 1

Frequency	Number of poles	Related rotating speed of motor (rpm)	Gear ratio	The rotating speeds of the first and second output shafts (rpm)
50 Hz	4	1500	2nd gear/ 4th gear	2020
	6	1000	=31/23=1.35	1350
60 Hz	4	1800	1st gear/ 3rd gear	2020
	6	1200	=28/25=1.12	1350

As is shown in Table **1**, even if the frequency of the alternating current changes from 50 Hz to 60 Hz, the rotating speed to be transmitted to the first and second output shafts can be maintained constant by moving the gear member **50** from the first position to the second position operating the lever **60**. It will also be understood that by this transmission gear means **9**, the related rotating speed of the drive motor **5** is increased to a rotational speed approximating the rotating speed of an ordinary diesel engine. Accordingly, it is possible to change a vehicle designed for a diesel engine to an electrically driven vehicle, without any change in design of the drive train.

In the embodiment shown in the drawings, two different frequencies are considered, but it is possible to adapt the gear means to changes of the frequency in three or more ways by combining gears in three or more pairs. Furthermore, in the embodiment shown, the rotating speed to be transmitted to the hydraulic motor is maintained constant irrespective of the frequency. Where it is not necessary to maintain pump speed at a constant value, the hydraulic pump **27** can be driven directly from the drive motor **5** without the medium of the transmission gear means **9**.

FIG. **5** shows an example of an electric circuit for controlling the operation of the vehicle **1**. An induction motor **5** having a six-pole configuration **5**A and a four-pole configuration **5B** and electric motors **23** and **35** for driving oil cooling fans are shown connected to a three-phase alternate current electric source S through switches. A control circuit **65** is also connected to the electric source S through a transformer **66**. The operation of the circuit is as follows: When a switch **67**A of the control circuit **65** is closed, relays **68** and **69** are excited and normally open contacts **68A** and **69A** are closed. As a result, the electric motor **23** and **35** start to be driven. Electric current is also supplied to an electric service meter **70.** If desired, current is also supplied to an illuminating light **72** by closing a switch **71.**

Either one of the switches **67B** or **67C** is selected according to the operating environment of the vehicle **1.** When it is desired to operate the vehicle **1** at a relatively low speed, (for example, when the vehicle runs in a tunnel for the site of operation), the switch **67B** is closed, and when it is desired to operate it at a relatively high speed, the switch **67C** is closed. When the switch **67B** is closed, the relay **73** is excited to close the normally open contact **73A**. As a result, power is supplied to the six-pole configuration **5A** of the induction motor **5**. On the other hand, when the switch **67C** is closed, the relay **74** is excited to close the normally open contact **74A**. As a result, power is supplied to the four-pole configuration **5B**.

In the circuit shown in FIG. **5**, a leakage detector **77** having a solenoid **76** for opening a circuit breaker **75**, an ammeter **78**, and a voltmeter can be provided in order to secure operating safety.

By referring to FIG. **6** which shows a control panel **80** of the vehicle **1**, a switch mechanism **67** for operating the three switches **67**A, **67B** and **67C** of the control circuit **65** will be described. These switches are operated by a single lever (not shown). When the lever is at the position **81**, these switches are all open. When the lever is moved to the position of **81A**, the switch **67A** is closed, and the switches **67B** and **67C** remain open. When the lever **81** is moved to the position **81B**, the switches **67A** and **67B** are closed but the switch **67C** remains open. Further, when the lever is transferred to the position **81C**, the switches **67A** and **67C** are closed, and the switch **67B** is open.

The performance of an electric driven tractor loader in accordance with this invention was compared with that of a diesel engine driven tractor loader, and the results are shown in Table **2** below. The tractor loaders used in this test had a capacity of 11 tons, and were the same except for the drive motor **5** and its accessories.

Table 2

	Diesel engine driven tractor loader	Electrically driven tractor loader
Main motor	Diesel engine (Rating: 96 PS, 2200 rpm)	Three-phase cage-type induction motor (Rating: 60 Hz 440 V - 70 KW, 1770 rpm; 50 Hz 400 V - 70 KW, 1460 rpm) (Gear ratio of the gear means: 60 Hz - 1.12 50 Hz - 1.35)
Speed of the tractor loader (Km/h)		
Forward movement		
1	3.0	2.8
2	5.6	5.4
3	9.3	9.1
Backward movement		
1	3.6	3.4
2	6.8	6.6
3	11.3	11.1

Since the electrically driven vehicles in accordance with this invention include transmission gear means, the speeds of the vehicle performance are constant irrespective of the frequency of alternating current used. Further, the performance is substantially the same as a diesel engine driven vehicle having the same structure except the drive motor and its accessories.

While the present invention has been described with reference to the preferred embodiment shown in the accompanying drawings, it should be understood that various changes and modifications in the minute parts of the drive may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. In an alternating current electrically driven industrial vehicle compatible with both 50- and 60-cycle operations having a drive train and a vehicle transmission, an electric drive comprising:

an electrical induction motor having an output shaft mounted on said vehicle, said induction motor having at least two operable pole configurations;

a secondary transmission operably disposed between said output shaft and the vehicle transmission operable to connect said induction motor to said vehicle transmission at differing gear ratios compatible with both 50- and 60-cycle operation of said induction motor whereby the input to said vehicle transmission will be the same at both 50- and 60-cycle operation of said induction motor;

switching means connected to said induction motor and operable to connect alternate pole configurations of said motor to an alternating power source; and

means connecting said switching means to an alternating electrical power source whereby the speed of the vehicle can be varied both by said vehicle transmission and by selection of at least two different pole configurations of said induction motor, thereby more efficiently adapting the vehicle capability to its working requirements.

2. The electric drive defined in claim 1 wherein the electrical induction motor has a four- and a six-pole configuration.

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