

[54] **MULTICABLE DRUM HOISTING SYSTEM**
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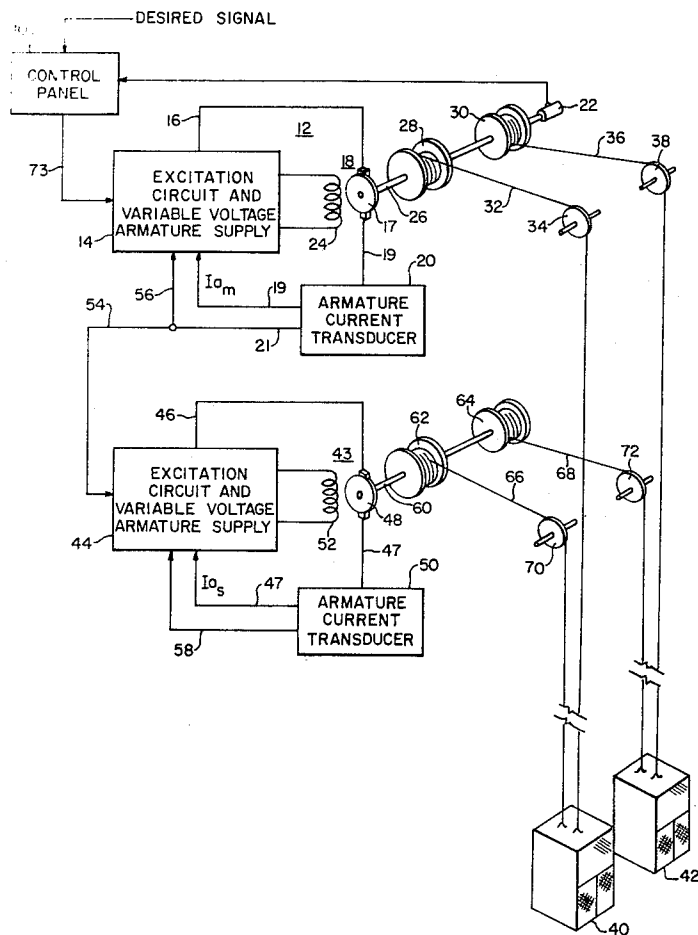
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[57] **ABSTRACT**

This invention relates to a multi-rope drum hoist wherein two conveyances are to be moved in opposite directions by the hoisting machinery at the same time. Each conveyance is hoisted by the use of two or more ropes, and the tension in the two ropes is equalized by providing a separate hoisting machine for each rope and coupling the hoisting machinery together electrically so that the torque outputs of the respective driving motors driving the separate hoists are essentially equal, thus assuring equal tension in the hoisting ropes.

11 Claims, 2 Drawing Figures



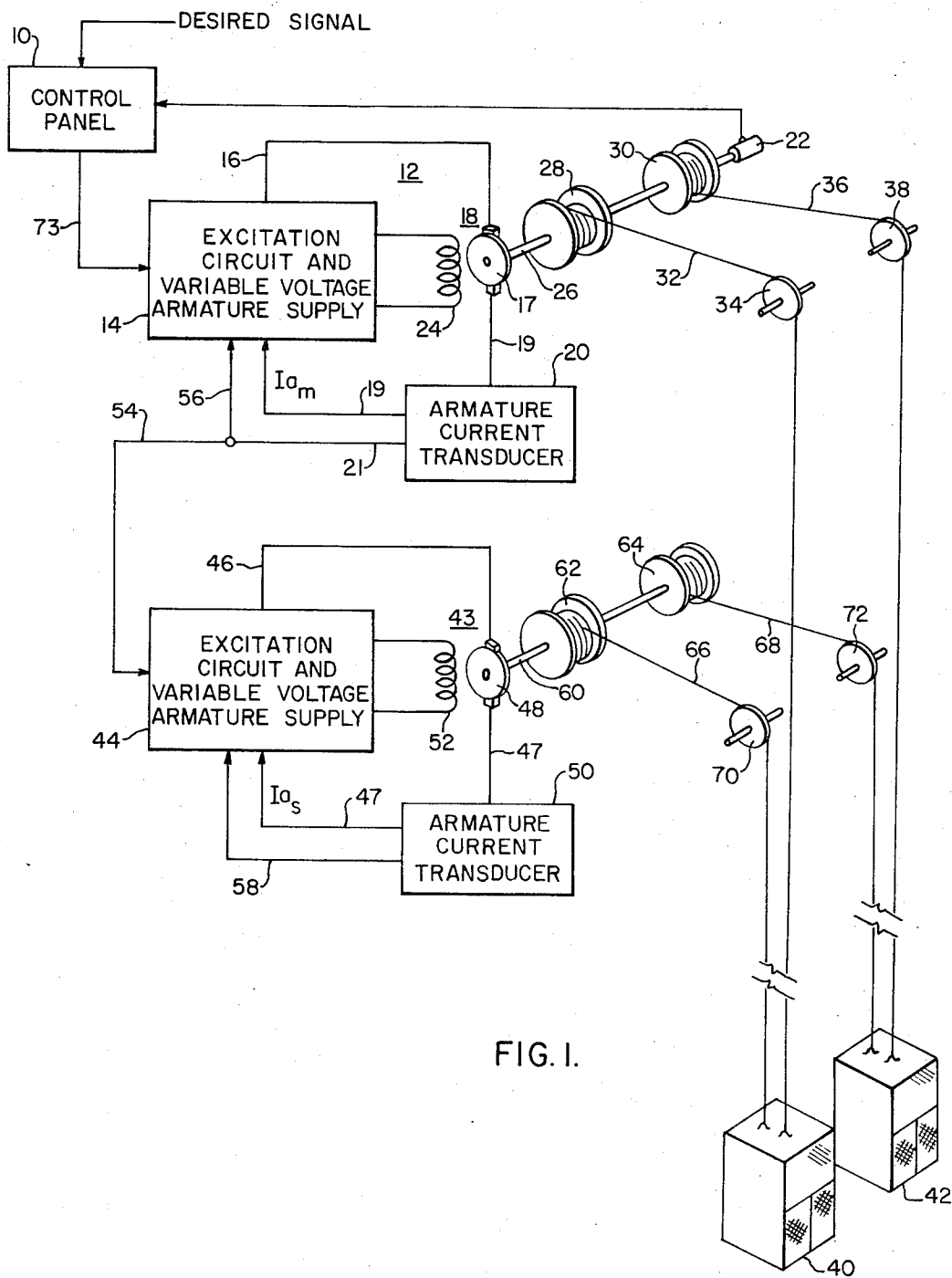
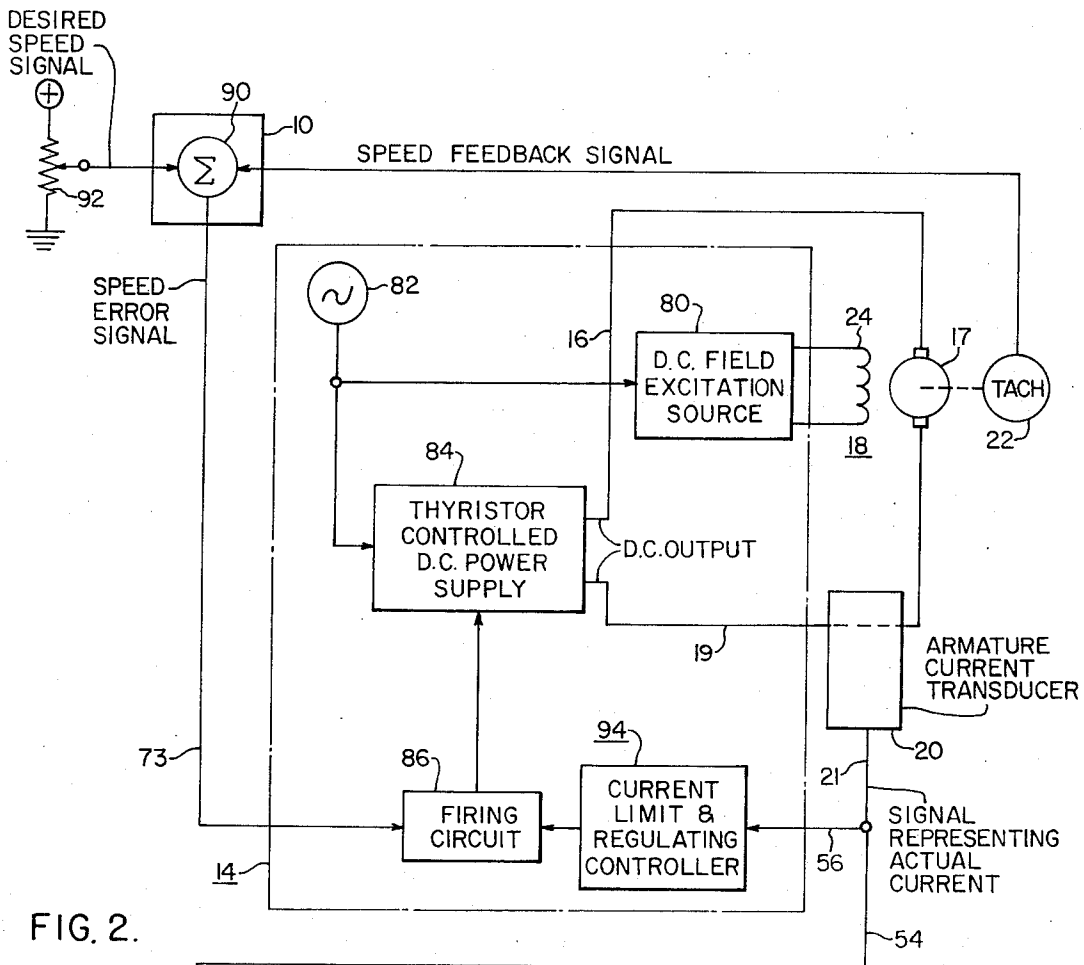
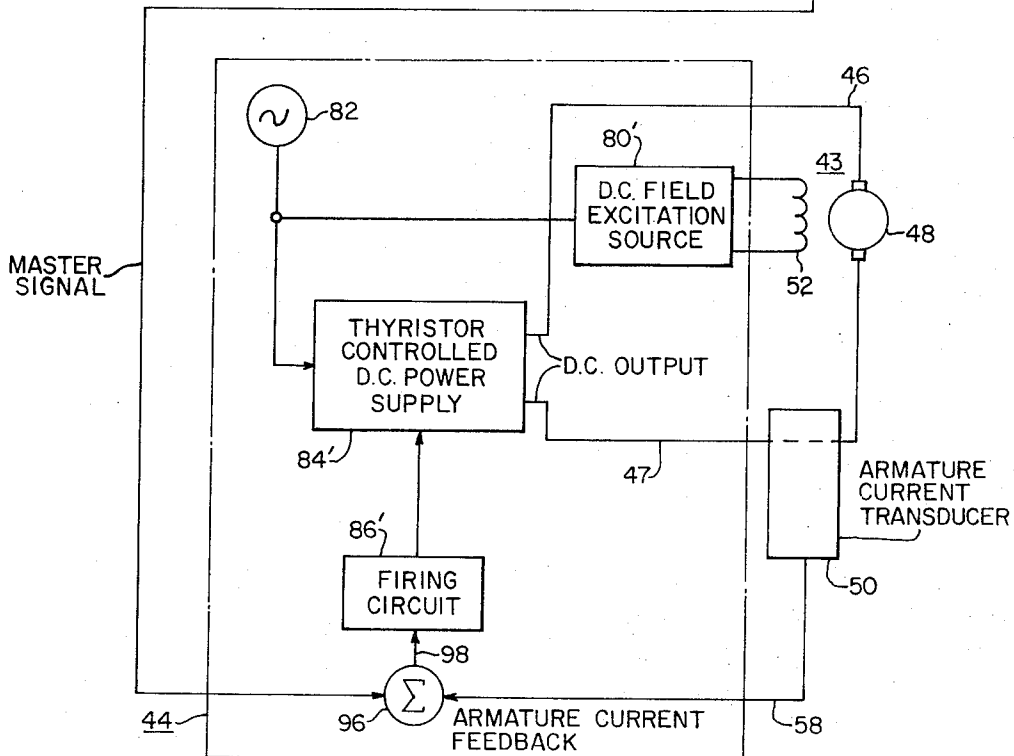


FIG. 1.



MULTICABLE DRUM HOISTING SYSTEM

CROSS-REFERENCES

None.

BACKGROUND OF THE INVENTION

Many types of mine hoists are in general use throughout the world, but upon detailed analysis, most of these hoists will fall into one of three main categories. Basically, the types are as follows: a drum hoist, a friction or a Koepe hoist, and a Blair hoist.

Drum hoists may take on several basic forms, all of which involve storage on a rope or a drum or a series of drums. The simplest form of drum hoist consists of a drum to which one end of a steel rope is attached, and the rope is wound under tension on the drum to hoist the conveyance. The rope generally passes from the drum over a pulley called a "head sheave" and down the mine shaft where it connects to the top of the conveyance. If, as is more usual, hoisting is done on a double-drum hoist, a pair of rope storage drums are located on the same driving shaft and are driven by the same energy source. The ropes are arranged to be coiled on the two drums in opposite directions and taken over two head sheaves to two conveyances. Rotation of the shaft, causing rotation of the drums in the same direction, causes one conveyance to be raised while the other is lowered. Generally, one of the drums is arranged to be declutchable from the driving shaft to allow the relative positions of the conveyances to be adjusted to compensate for rope stretch or other factors which change the distance between the two conveyances.

Friction hoists or Koepe hoists as they may be called, have been increasing in favour in recent years due to the more efficient operation and the lower installation cost of this hoist. Its principal is similar to that of a commercial elevator in that one end of a head rope is attached to the top of one conveyance, while the rope is taken over a parallel-grooved wheel situated directly above the conveyance, and the other end of the head rope is attached to the top of the other conveyance in the shaft. The bottoms of the conveyances are generally connected together by a tail rope.

The advantage of a friction hoist over a drum hoist lies in the efficiency of installation and operation and in the use of many ropes on the friction wheel, instead of a single rope on a drum hoist. Because of the coiling problems it is not feasible to coil more than one rope on a drum of a drum hoist. Also, the drum must be more massive to withstand tremendous crushing forces of several layers of highly stressed rope wound thereon. Storage space for essentially all the rope necessary to hoist the conveyance dictates the size of the drum.

A friction hoist may be mounted directly above the conveyance in the head frame, but the drum hoist must be located some distance from the head sheave because of the necessity of maintaining a fleet angle between the rope of the head sheave, which angle must be kept small to insure proper coiling.

The primary disadvantage of a friction or Koepe hoist for depths of up to 5,000 feet is that it is impossible to separate and adjust the conveyances as can be done with a double-drum hoist. Below 5,000 feet, the friction hoist has another major limitation which is caused by a variation in stress on the head ropes as the rope trav-

els over the wheel. It will be understood that the stress in the head rope must change drastically as the rope passes over the wheel due to the load removed therefrom; thus, where the ropes are long enough there is much stretching, straining, and twisting of the head ropes during the hoisting operation. This leads to rapid head rope wear. It will be immediately seen that the strain on a drum hoist rope does not change during the hoisting cycle and this avoids rope wear resulting in a very definite advantage for very deep mines.

But problems are encountered in coiling large ropes on drums and it is generally believed that a decided advantage is to be gained by using a plurality of ropes on smaller drums. (There are severe legal restrictions on the minimum bending radius permitted for wrapping hoisting ropes about a drum). As an example, two 1½ inch diameter ultra-high strength tensile ropes have approximately the same ultimate breaking strength as one 2 inch diameter rope of the same type, but the two 1½ inch ropes may be wound on a drum of 30 percent smaller initial winding diameter than that required for the larger diameter rope. Four 5/16 inch diameter ropes could be wound on a drum of half the initial winding diameter of that required for a 2 inch rope. It is easy to see that designers of hoisting machinery can envisage major operation improvements if it were possible to assure that each individual hoisting rope of a group would carry its proportion of the load during any hoisting operation.

One more prior art hoist that has overcome severe disadvantages of the friction hoist and the drum hoist is the Blair hoist. This hoist uses a multi-rope idea with a declutching feature of the double-drum hoist. The hoist consists essentially of a means for coiling two ropes in parallel—one on each end of a drum, both connected to the same conveyance, and have mechanical means of equalizing the tension of the two ropes. This means consists of an equalizing wheel on which the two hoisting ropes are wound in opposite directions. The equalizing wheel is freely rotatable so that in a hoisting operation when the tension in one rope exceeds that of the other rope, such as might happen if improper coiling of the hoisting rope takes place on one of the drums, the equalizing wheel rotates and pays out rope to whichever rope in the higher tension, thus taking up rope from the one in lower tension, consequently adjusting the load and equalizing the tension in both ropes. It will be readily seen that there is a practical limitation to the amount of rope which may be stored on the equalizing wheel and consequently only a finite amount of adjustment may be made in this manner. The disadvantages of the Blair hoist are that the tension equalizing device is situated in a hostile environment, and the equalizing wheel adds additional weight where it can least be afforded, that is, on the conveyance. The other problem which immediately becomes evident is that only a finite amount of correction in tension is available by the equalizing wheel methods, and when this amount is exceeded the hoist must be shut down or the result would most certainly be a broken rope.

PRIOR ART REFERENCES

1. A Paper presented by Mr. J. Downon of British Wire Ropes Limited at the Annual General Meeting of the C.I.M.M., March 1965, entitled "Wire Ropes for Deep Shafts".

2. A Paper entitled "Multi-Rope Winding From Deep Levels", by Mr. R. Blair, addressed to the I.C.E., South Africa.

SUMMARY OF THE INVENTION

The hoist of this invention consists of two separate identical hoisting machines which are preferably of the doubled-drum hoisting type, and each hoist is supplied with energy from a motor which is of necessity energized from an electrical source, the output of which may be modulated quickly, for example, a source utilizing high speed current modulating devices, for instance controlled rectifiers such as thyratrons, thyristors, etc. One hoist is designated a master hoist and the other is designated a slave hoist for convenience. Both motors are supplied with electrical energy controlled for example by solid state devices which generally includes thyristors modulating the current to the motors. High speed control devices are necessary because of the speed of response required of each drive motor.

The master hoist is controlled from the control console in any of a number of well-known manners. It may be also run automatically. A power stage, for example a thyristor control stage supplies energy to the master motor in accordance with instructions from the control panel and, as is generally known, the amount of current passing through the armature generally is or can be made to be an accurate measure of the torque being produced on the shaft of the machine. Provision is made to sample the current being fed to the master motor and a transistor supplies a control signal to the control circuit for the slave motor. The controls in the slave motor attempt to keep the same current flowing in the slave motor as that in the master motor. The current flowing in the slave motor is sampled by a transducer and the corresponding signal is fed back into the control circuitry for the slave motor to assure that it does not in fact follow the current in the master motor. It is therefore seen that the torque in the slave motor is substantially equal to the torque in the master motor regardless of the setting of the control from the control panel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a partial schematic, partial diagrammatic illustration of a preferred embodiment of this invention; and

FIG. 2 is a diagram illustrating one example of circuit detail applicable to the control circuitry of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The following description will be directed to and describes in detail the operation of a hoist which receives mechanical energy from a dc motor having a fast response control circuit, for example one that is generally referred to as a "solid state" fast response control circuit, providing electrical energy thereto.

It is understood that other electrical energy converters such as a cyclo-converter coupled to an ac motor could be made to provide the same result provided the speed of response of the cyclo-converter was "fast" enough.

Referring now to FIG. 1, a control panel 10 is shown connected to the master control circuit generally designated 12. A control signal is fed into the excitation circuit of the variable voltage armature supply 14. The

control 14 supplies current to the armature 17 of the master motor 18 through a line 16 and a line 19 which is also arranged to be passed through a current transducer 20 that provides on its output line 21 a signal proportional to the armature current. A tachogenerator 22 supplies a signal proportional to the speed and direction of rotation of motor 18 to the control panel 10. (Alternatively the counter E.M.F. of the armature of the drive motor 18 may be used to provide the same information). The control circuit 14 also assures that the field winding 24 receives sufficient current for excitation purposes. Coupled to the armature 17 is a shaft illustrated as 26 on which are mounted a pair of drums 28 and 30. Drum 28 is provided with a rope 36 which passes over head sheave 34. Drum 30 is provided with a rope 36 which passes over head sheave 38. Rope 32 is fastened to conveyance 40 and rope 36 is fastened to conveyance 42. The slave circuitry is as follows.

The excitation and the variable voltage armature supply for the slave motor 43 is provided by control 44. The armature current for the slave motor is provided through conductors 46 and 47 to the armature 48 of the slave motor. Provision is made for monitoring the armature current in transducer 50. The field of the slave motor 43 is arranged to be excited by means of field winding 52 supplied from control 44. A signal from the armature current transducer 20 is arranged to be fed by means of conductor 54 into the control circuit 44 of the slave motor. Provision is also made for supplying a signal proportional to the armature current of the master motor into the excitation circuit and variable voltage armature supply 14 by means of conductor 56. Conductor 58 also supplies a signal to control 44 which is proportional to the armature current flowing in the slave motor 43. Connected to the slave motor armature shaft is a shaft 60 on which are mounted a pair of drums 62 and 64 on which are mounted a pair of wire ropes 66 and 68 respectively. Wire rope 66 is connected to conveyance 40 and rope 68 is connected to conveyance 42.

OPERATION

The operator sets a control on the control console, which is proportional to the desired speed of the hoisting machinery. An output signal is reduced on line 73 which is proportional to the error between the actual speed as measured by tachogenerator 22 and the desired signal.

Upon the presence of an error output signal from the control panel 10, the control circuit 14 will supply energy to the armature 18 of the master motor. As soon as current begins to flow in conductor 16 the armature begins to rotate and current transducer 20 will supply a signal via conductor 54 to the control 44 for the slave motor. Immediately the control 44 will call for the same armature current to flow in conductor 46. The feedback links from the two armature current transducers 20 and 50 will assure that the actual armature current which is desired will flow in both armature circuits. This will cause the armatures to rotate with identical torques, thus assuming clockwise operation of both motors, conveyance 40 will be lowered into the shaft while conveyance 42 will be raised with the ropes 36 and 68 such that the tension in both ropes will be essentially equal due to the control circuits operating in their proper control modes.

Exemplary detail for controls 14 and 44, i.e. the excitation and variable voltage armature supply systems for both motors, is shown in FIG. 2. In that figure, dc field excitation sources 80 and 80', whose dc outputs are connected to field windings 24 and 52 respectively, receive and rectify current from an ac source 82 which also supplies power to variable voltage dc sources 84 and 84' whose dc outputs are connected to the armatures 17 and 48, respectively. Each of the dc sources 84 and 84' includes thyristors for rectifying ac from source 82 to provide the dc for the associated motor armature. The thyristors of the sources 84 and 84' are phase controlled by firing circuits 86 and 86', respectively, in response to input control signals applied to the control input lines of the firing circuits.

A speed error signal from the control panel 10 is supplied along a line 73 as a control signal to the firing circuit 86. The speed error signal is shown as being developed in a summing circuit 90 which effectively compares a desired speed reference signal from a suitable adjustable reference source 92 with an actual speed feedback signal from the tachogenerator 22.

In order to control and limit the value of the armature current, a current limit and regulating controller 94 which responds to the armature current reaching prescribed limits supplies in accordance thereto control signals to the firing circuit 86. Thus the power supply 84 produces an output in accordance with the speed error signal modified as desired by current controlling signals responsive to armature current, thereby to maintain desired speed and proper torque on the motor 18 throughout the complete housing or loading duty cycle. A signal proportional to armature current is supplied to the input line 56 of controller 94 by the armature current transducer 20 which may be any suitable device for that purpose, for example it may include known transducer arrangements serving in effect as a dc transformer.

The armature current signal from transducer 20 is used as a command or desired current signal for armature 48. This command signal is supplied along line 54 to an input of an error generator 96 where it is compared with an armature current feedback signal from the armature current transducer 50 to provide an error signal along a line 98 to the control input of firing circuit 86', whereby the firing circuit 86' controls the power source 84' to make the armature current and torque of motor 43 follow the armature current and torque of motor 18.

This entire scheme is made feasible only by the presence of fast response controlled armature power supplies, for example thyristor controlled armature supplies, in which it is quite simple to monitor the armature current in the armature of the machine and make fast adjustments when necessary. Without this feature, it would be impossible to impose severe limitations on the armatures of the machine, thus giving the equal torque at the shafts of the machines.

It is quite simple to insert a safety device in the armature of either machine to assure that the armature current in either machine never exceeds a safe value, otherwise the apparatus will be shut down, and in the event of a shutdown, a suitable brake will of necessity bring the hoist to rest.

As a final protective measure, it is possible that the stresses in the two ropes may be measured electrically, the signal produced may be used to trip out the hoist

if the difference in stress does exceed a certain predetermined amount. This is made possible by monitoring the difference of the two currents flowing in the two armatures multiplied by the distance travelled by one of the hoists, preferably the master hoist. The product of the difference in current times the distance travelled will give a good indication of the difference in stress of the two ropes.

In summary, this invention provides a practical way of equalizing the stresses in two or more ropes which are coiled on separate drums by driving one of the drums with a current regulated motor. One of the main advantages would be due to the fact that both circuits are essentially identical. Because the motors are identical, the initial capital investment is somewhat less than it might have been and the acquisition and storage of spare parts becomes a more efficient operation.

While the operating mode example herein is directed to equal currents and equal torques in the master and slave motors, the control concepts of the invention may be incorporated in a system for operation in a mode where the predetermined relationship to be maintained between the motor currents and between the motor torques is other than equal.

It should be understood that the disclosed embodiments and components are employed by way of example only and are not intended to limit the invention to the specific example as shown.

I claim:

1. A master-slave motor system comprising a first electro-mechanical apparatus including a master motor drivingly coupled to a hoist device, an associated hoisting cable and a load to be lifted and lowered;

at least one additional electro-mechanical apparatus including a slave motor drivingly coupled to a corresponding hoist device and hoisting cable, and said load;

whereby said hoist devices and hoisting cables operate in a parallel load sharing relation with said load; means responsive to a variable of the master motor for providing a command signal proportional to the output torque of the master motor; and control means responsive to the command signal for controlling the slave motor to maintain its output torque in a predetermined relationship with the output torque of the master motor.

2. The system of claim 1, wherein said predetermined relationship is torque equality.

3. The system of claim 1, wherein each of said hoist devices is a drum hoist and each of said associated hoisting cables is wound on a corresponding drum.

4. The system of claim 3 wherein in at least one of said electromechanical apparatus the associated hoist device is coupled with a second drum, said second drum being coupled to a second load through a second hoisting cable;

wherein said second hoisting cable is wound on said second drum in the opposite direction as compared to the associated drum and hoisting cable within said one electromechanical apparatus; and with the former load being lifted when the latter said second load is lowered.

5. The system of claim 4 wherein a second drum and a second hoisting cable are provided in each of said electromechanical apparatus, each of said second drums and second hoisting cables being coupled in common to said second load.

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6. The system of claim 1, wherein each of said master and slave motors is a DC motor having an apparatus current and voltage supply and a field excitation provided from a supply including semiconductor controlled rectifiers.

7. A master-slave motor system comprising a master motor drivingly coupled to a first hoist having a hoisting cable, a slave motor drivingly coupled to a second hoist having a hoisting cable, both hoisting cables being coupled to a common load, whereby both hoists operate in parallel in load sharing relation to one lifting and lowering the load, means responsive to a variable of the master motor for providing a command signal proportional to the output torque of the master motor, and control means responsive to the command signal for controlling the slave motor to maintain its output torque in predetermined relation with the output torque of the master motor.

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8. The combination as in claim 7 wherein said predetermined relation is equality.

9. The combination as in claim 7 wherein said variable is motor armature current.

10. The combination as in claim 9 wherein there is means for providing a feedback signal responsive to the armature current of the slave motor, and said control means is responsive to the feedback signal for maintaining the torque output of the slave motor at the value dictated by the command signal.

11. The combination as in claim 9 wherein there is means for providing a feedback signal responsive to the armature current of the slave motor, and said control means comprises a current regulating system wherein the command and feedback signals are compared to produce an error signal, and means responsive to said error signal for controlling the slave motor.

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