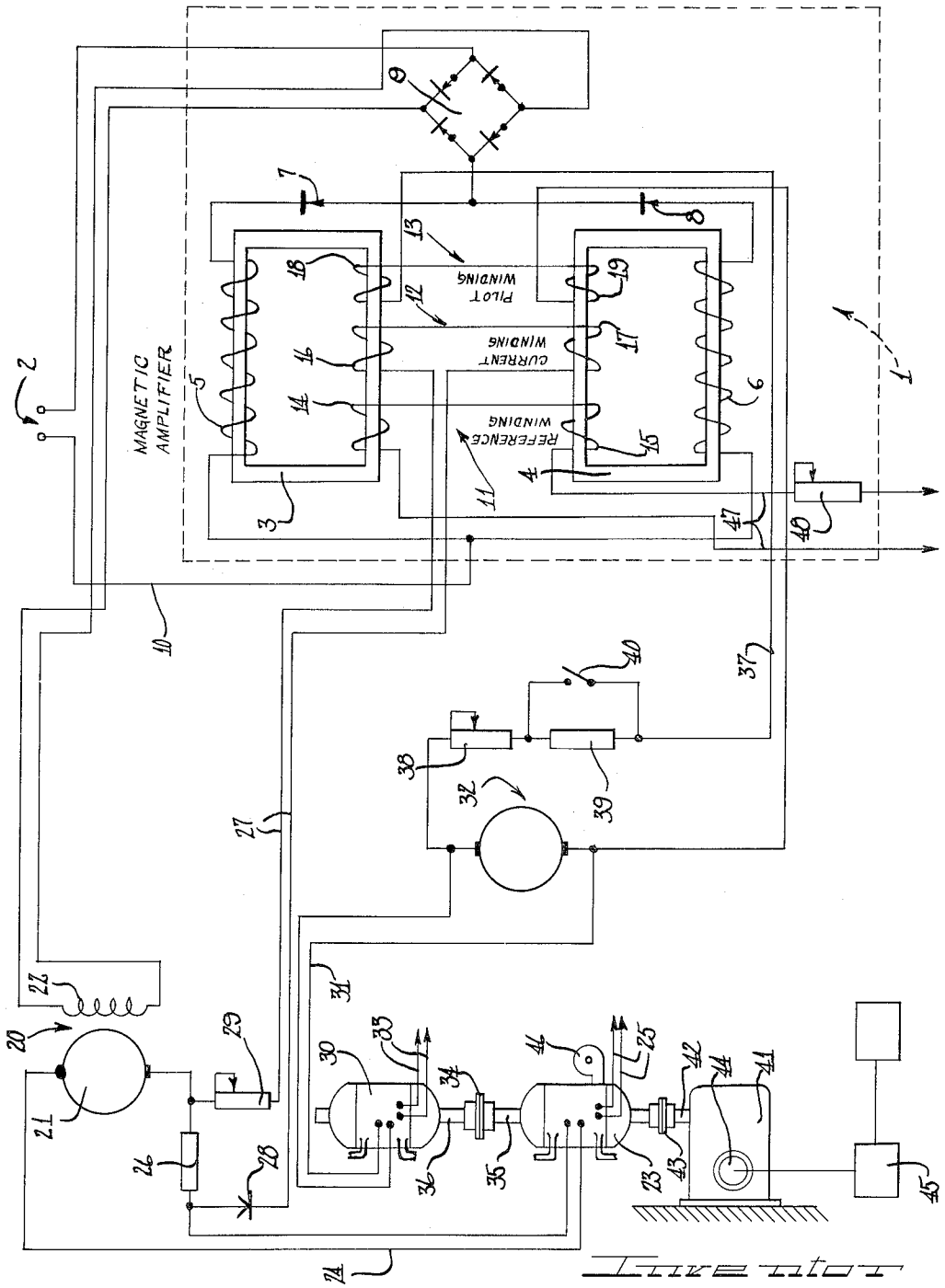
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ELECTRIC MOTOR CONTROL AND COUNTERWEIGHT COMPENSATOR

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ELECTRIC MOTOR CONTROL AND COUNTERWEIGHT COMPENSATOR

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The present invention relates to an electric counterweight compensator. More particularly the present invention relates to an electric drive control system for controlling the mechanical rotational output of an electric motor mechanism.

Systems embodying the principles of the present invention are readily adaptable to advantageous employment in many environments. One of the most advantageous uses of a system embodying the principles of the present invention, however, is in conjunction with furnaces and particularly electric furnaces where it is necessary to provide counterweight compensation means for raising and lowering the furnace electrodes and mast thereon.

Non-counterweighed furnace electrodes are extremely massive and weighty devices which require carefully controlled raising and lowering systems to operate the same properly and safely. Controlled electric drive systems embodying the principles of the present invention are well adapted for such rugged use and intermittent operation.

Systems embodying the principles of the present invention provide a torque motor or similar electric motor drive mechanism for driving the winch motor or the like through a gear reducer mechanism for counterweight compensation and raising and lowering the electrodes. The motor circuit is controlled in accordance with the principles of the present invention most effectively and efficiently through a magnetic amplifier system for driving the motor to raise the door and to provide dynamic breaking when lowering the electrodes.

It is an important object of the present invention to provide a controlled electric drive system.

It is another important object of the present invention to provide a controlled counterweight compensation system.

It is still another important object of the present invention to provide a new and improved controlled electric drive system operating through an improved magnetic amplifier control device.

It is still another object of the present invention to provide an improved electric drive system with a control system including magnetic amplifier controlled energization mechanism.

It is still another object of the present invention to provide a controlled rotary output electric drive system with an improved energization system controlled through an improved magnetic amplifier system.

Still other objects, features and advantages will become apparent and readily present themselves from the following detail description of the present invention and a preferred embodiment thereof, from the appended claims, and from the accompanying drawing illustrating a preferred embodiment of the present invention and forming an integral part of this specification and disclosing fully and completely all details shown thereon.

On the single figure of drawing there is illustrated a preferred system embodying the principles of the present invention. This system preferably includes a magnetic amplifier 1 which couples an alternating current input of substantially constant voltage, as at 2, into the system. Magnetic amplifiers, which per se have been known in the art, are sometimes called direct current transformers. This is an appropriate name for them since the output of a magnetic amplifier is controlled through a direct current input and it is possible to attain a gain of as high as ten million. A magnetic amplifier consists essentially of a magnetic core and a multiplicity of coils of wire. One or more input or control coils are fed the input direct current control to control the power available from output or power coils. The power source is provided from an alternating current power line or the like and magnetic amplifiers may be designed to operate efficiently within the range of from about 60 cycles to about 1000 cycles.

By way of background, the magnetic material when subjected to a magnetization force (H) of increasing intensity will develop an increasing flux density (B) until the magnetic material approaches saturation at which point the rate of increase of flux density will decrease until actual saturation is reached. Demagnetization of the core material and remagnetization in the opposite direction by an opposing magnetization force will develop an opposing flux density until saturation in the opposite direction is reached through a range of decreasing rate of increase of flux density in the opposite direction. With a perfect, no loss, magnetization material a chart of the density versus magnetic force of field intensity will have the appearance of a stretched out S with the center of the S running through the origin of the curve.

Operating in the central region of this curve, that is, in the region of this curve between the sharply arcuate knee section where the rate of increase of flux density is sharply diminishing, a coil wrapped around a piece of magnetic material such as in an electromagnet or an inductor or in a transformer, will develop a high self inductance (L) and therefore a high inductive reactance. If on the other hand the coil or inductor or transformer or the like is operated with the core material magnetically in the saturation range energizing current through the coil will encounter only the very slight impedance of the resistance of the wire in the coil. Operation of the system such as on the knee of the curve will permit great variations in the current flow through the coil for small variations in the magnetization force or flux density since in preferred magnetic materials for use in conjunction with magnetic amplifiers of the knees of the curves are relatively sharp.

In the magnetic amplifier the control coils are preferably energized with a direct current to a level where the core material is being operated at about the knee of the curve. Other coils on the core interconnecting the alternating current supply source and the load are then permitted large variations of current with small variations in the direct current flowing through the control coil or input coil.

With the foregoing general discussion in mind operation of the magnetic amplifier 1 of the system of the present invention may be more readily and clearly understood. The magnetic amplifier 1 is provided with a pair of closed circuit core elements 3 and 4 which are preferably composed of a material of high permeability such as Permalloy or Mu-metal. The cores 3 and 4 are illustrated as separate individual closed circuit cores, that is, magnetically closed circuits, since that is a preferred form therefor in accordance with the principles of the present invention, but these cores may be united or formed as a single core of similar material having three cross legs and a pair of interconnecting longitu-

dinal legs. A pair of power or output coils 5 and 6 are provided one on each core 3 and 4, respectively.

These coils 5 and 6 are connected in parallel opposing relation and preferably are interconnected at one end of each with a pair of rectifier devices which both conduct in the same direction. These rectifier devices may be identified on the drawing by the numerals 7 and 8, respectively. A full wave rectifier bridge system 9 interconnects one side of the alternating current power source 2 to a conductor point between the rectifier devices 7 and 8. The other side of the alternating current input power source 2 is connected to the opposite end of the coils 5 and 6 by way of a conductor. In this manner of circuitry in accordance with the principles of the present invention, the system is operable to control direct current output when provided with a constant potential alternating current source input. The output from the system is taken from across the rectifier bridge network 9.

If it is desired for other purposes to provide output of a controlled alternating current then the rectifier bridge may be omitted and the load connected in series with the constant potential alternating current input power source and the magnetic amplifier parallel opposed output coils 5 and 6.

The magnetic amplifier 1 is also provided with several sets of control windings. In the preferred embodiment of the present invention illustrated on the drawings three such sets 11, 12 and 13 are provided on the magnetic amplifier. Each of the sets 11, 12 and 13, respectively, includes a pair of series aiding coils with one of each sets on each of the core members 3 and 4. That is, the control winding set 11 has a pair of series aiding connected coils 14 and 15 with the coil 14 wound on one leg of the core member 3 and the coil 15 wound on one leg of the core member 4; the control winding set 12 has a coil 16 wound on one leg of the core member 3 and a series aiding connected coil 17 wound one leg of the core member 4; the control winding set 13 has a control coil 18 wound on one leg of the core member 3 in series aiding with control coil 19 wound on the core member 4. Preferably, the coils 14, 16 and 18 are wound in magnetic aiding relation each on the same leg of the core member 3 and the coils 15, 17 and 19 are preferably similarly wound in magnetic aiding direction each on the same leg of the core member 4.

If it is desired to use a three legged core in lieu of the two cores described, then the several sets of control windings may each be reduced to single coils wound in magnetic aiding relation on the center leg of such a core, the output or power coil being wound on the end legs of that core.

A direct current generator 20, which, in accordance of the principles of the present invention, may be considered as a torque generator, includes an armature 21 and a field winding coil or coils 22. The field winding 22 is connected to the output terminal of the four-way rectifier bridge 9 to receive unidirectional current through that coupling system. The armature 21 of the torque generator 20 is preferably driven, rotatably, at a substantially constant speed and is connected to input terminals of a torque motor 23 through electric coupling leads 24. The coupling leads 24 are preferably connected to the armature circuit of this direct current rotary power output torque motor mechanism, the field of the motor 23 being connected to substantially constant potential source of direct current through leads 25.

An armature current sensing element, such as a resistor or the like, 26 is connected in series with the armature 21 of the torque generator 20 and the armature current leads 24 of the output motor 23. Current signal leads 27 connected across the sensing element 26 couple the current signal output of the sensing element 26 directly to the current winding set 12 of the magnetic amplifier 1. A blocking type rectifier element 28 and a variable

control potentiometer 29, which is preferably a rheostat or the like, is connected in series with the leads 27 for controlling the current through the current winding set 12 of the magnetic amplifier 1 and to prevent reverse current flow therethrough under conditions further described hereinbelow.

A second motor mechanism 30 which is herein operable as a regulator motor and is substantially identical in construction to the torque motor 23, has preferably its armature terminals connected through leads 31 to the opposite sides of a regulator generator 32. The field windings of the regulator motor 30 is connected through leads 33 to a constant potential direct current source which may be the same as the one connected to the leads 25 for the field winding of the output motor 23. A flexible direct coupling member 34 or the like directly and positively connects the shaft 35 of the output motor 23 and the shaft 36 of the regulator motor 30.

Regulator generator 32 is also connected at its opposite sides through leads 37 of the control winding set 13. The control winding set 13 including coils 18 and 19 may be best identified as a pilot winding set. In series with the pilot winding set 13 and the regulating generator 32, electrically, is a second control rheostat 38 or the like and a regulator generator output limiting element 39 which is preferably a resistance element or the like. The master switch raise contacts 40 are connected directly across the limiting element 39 for operation of the system as further described hereinbelow.

The output rotational drive of the system is provided by coupling the output motor or torque motor 23 to a gear reducer mechanism 41 with the input shaft 42 of the gear reducer positively coupled to the shaft 35 of the output motor 23 through the coupling mechanism or the like 43. The output shaft 44 of the gear reducer mechanism 41 may be connected to a winch motor or the like 45, and therethrough to the door mechanism or the like.

It will be described immediately below, in accordance with the operation of the system embodying the principles of the present invention, the torque motor or output motor 23 is required under operating conditions to stand for long periods with high armature current flowing therethrough. To cool the motor and prevent burning of the same, a blower fan or the like 46 is connected thereto to blow cold or cool air through the motor 23.

In addition to the above described details of this preferred embodiment of the present invention, the remaining or control winding set 11, herein referred to as a reference winding set including the coils 14 and 15, is connected to a source of substantially constant potential direct current through leads 47. A third control rheostat or the like 48 is connected in series with the reference winding 11.

From the above detail description this preferred embodiment of the present invention and further from the general discussion of the operational characteristics of magnetic amplifiers, it will be clear by proper control of the current flow through the reference winding 11, current winding 12 and pilot winding 13, current flow through the field winding 22 torque generator 20 from the potential alternating source 2 may be controlled in any desired manner.

The operation of the preferred system structurally and electrically described in detail above provides a very efficient control for the output motor 23 whether it is called upon for frequent output power or infrequent output power.

The operating cycle or sequence of operation of the system of the present invention provides, as stated, an efficient control for the torque motor 23. With the rheostat or the like 48 properly adjusted, the reference winding 11 is adjusted as to change the alternating current impedence to permit current to flow through the full wave rectifier bridge circuit 9 and the output power

coils 5 and 6 from the constant potential alternating current source 2 to the field winding 22 of the torque generator 20. Proper adjustment of the rheostat 48 so energizes the fields of the torque generator 20 that armature current flows a value just below the brakeway point for the torque motor 23; the torque motor thereby remaining at a standstill position. Thereafter, for example, for raising furnace electrodes the master switch on a general control panel is turned to the raised position. This closes the contacts 40 thereby shorting out the regulator generator output limiting element 39 impressing the output of the generator 32 across the pilot winding 13 allowing more current to flow through this winding and thus generating additional flux which is additive to that of the reference winding and effective to still further decrease the impedance and self inductance of the input power coils 5 and 6 of magnetic amplifier 1. This further reduction in the impedance of the output coils or power coils 5 and 6 of the magnetic amplifier 1 permits an increased current to flow through the field winding 22 of the torque generator 20. The torque generator 20 then builds up further increased potential and thereby transmits an increase current to the torque motor beyond the brakeway point.

Up until this point a relatively high current has been flowing in the armature circuit for the torque generator and torque motor thereby impressing a relatively high potential across the current sensing element 26 and therefore relatively high current has passed through the current winding 12 creating a flux in additive relation to the flux of the reference winding 14. This general relation between the several windings permits the efficient control for raising provided by this system. Past the brakeway point the current winding flux decreases to a low value however since rotation of the torque motor operates to reduce the armature current therein through the back e. m. f. generated in the motor. The torque motor will nevertheless continue to operate so long as the main switch raise contacts 40 are closed by virtue of the higher potential impressed across the motor by the generator 20.

As soon as the master switch is released, however, the pilot winding flux is reduced substantially to zero value. Since the reference winding is not strong enough to maintain acceleration, the torque motor stalls and this builds up the current across the torque generator drop resistor thereby allowing the flux to build up in the current winding and in turn the torque generator is again energized to a voltage immediately below the brakeway point for torque motor 23.

Lowering of the furnace electrodes or the like is preferably best accomplished by what may be termed a manual operating system. Release of the electrodes from their formerly raised position, raised as described hereinabove in accordance with the principles of the present invention, tends to let them fall at a speed that would greatly accelerate if braking power was not provided thereagainst. The system of the present invention also provides an efficient dynamic braking system. Upon release of the furnace electrodes or the like, the winch motor rotates in an opposite direction and thereby drives the torque motor and the regulator motor in an opposite direction to their raising direction or their normal motor operating direction. Through reverse rotation of the regulator motor, the regulating generator will build up the flux in the pilot winding to oppose the flux in the reference winding and current winding. As the winch motor drives the torque motor in its opposite rotational direction, the torque generator voltage falls off due to the flux in the pilot winding. This will also decrease the current for the flux in the current winding still lowering the torque generator voltage. The torque motor having full field current and being driven reversely by the winch motor generates a voltage loading back to the torque generator and the torque generator now acts as a brake controlled by the current winding and pilot winding. The blocking rectifier 28 in the current winding signal system prevents any possibility of reverse current through that winding and any possibility of reduced impedance here. Adjustment of the rheostat 29 in the regular generator circuit or pilot winding circuit and in the current winding circuit, respectively, provides very sharp and critical control elements for this system.

From the foregoing it will be clearly understood that in accordance with the principles of the present invention a very efficient and advantageous electric drive control system is provided.

While I have shown and described a particular embodiment of my invention, it will, of course, be understood that I do not wish to be limited thereto since many modifications may be made, and I, therefore, contemplate by the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

I claim as my invention:

1. An electric drive control system comprising, a magnetic amplifier, a plurality of power windings in said magnetic amplifier, electric drive means, an energizing control source coupled to said electric drive means, a power source connected to said energizing control source through said power windings of said magnetic amplifier, means coupling one of said control windings of said magnetic amplifier to said electric drive means and said energizing control means, a second of said plurality of control windings of said magnetic amplifier coupled to a potential source through a variable control element, and a control signal source coupled to another of said control windings, said control windings being so oriented in said magnetic amplifier that additive signals of preselected value influence said energizing control source to operate said electric drive means for driving a load in one direction, and so that opposing signals influenced the system for controlling operation of the load in an opposite direction.

2. An electric drive control system comprising, a magnetic amplifier including a plurality of power windings and a plurality of control windings, an electric drive mechanism, an energizing control system coupled to said electric drive mechanism and to one of said control windings, said power windings also being coupled to said energizing control system, a second of said plurality of control windings of said magnetic amplifier coupled to a potential source through a variable control element, and a control signal source coupled to another of said control windings, said control windings being so oriented within said magnetic amplifier that additive energization thereof above a preselected level influences said power windings and said energizing control system to operate said electric drive mechanism for driving a load in one direction, and so that opposing signals influenced the system for controlling operation of the load in an opposite direction.

3. A control electric drive system comprising, a power output electric motor mechanism operably arranged to provide rotary mechanical power to a system to be driven thereby upon energization by armature potential above a preselected value therefor, said motor mechanism being further operably arranged to provide a reverse electric output upon being driven by said system to be driven, an energization system including a first control generator mechanism coupled to said motor mechanism to provide armature current and potential thereto under selected conditions and to accept armature current therefrom when said motor mechanism is driven by said system to be driven, a second motor mechanism coupled to said power output electric motor mechanism, a second generator mechanism electrically coupled to said second motor mechanism and operably arranged to accept energization from said second motor mechanism when said power output motor mechanism is driven by said system to be driven, and a control system arranged to control excitation of said first generator and coupled to said motor mechanism and said second generator mechanism to derive operating signals and control signals therefrom.

4. In an electric drive control system wherein the input to a generator is controlled by a multiple control winding magnetic amplifier to control operation of the motor energized from said generator and wherein a control winding of said magnetic amplifier receives its signal from said generator and another control winding receives its signal from a reference source, the improvement comprising a second motor coupled to the first motor for co-rotation therewith, a second generator for energizing said second motor, and means coupling said second generator to still another control winding on said magnetic amplifier.

5. In an electric drive control system wherein the input to a generator is controlled by a multiple control winding magnetic amplifier to control operation of a motor energized from said generator and wherein a control winding of said magnetic amplifier receives its signal from said generator and another control winding receives its signal from a reference source, the improvement comprising a second motor coupled to the first motor for co-rotation therewith, a second generator for energizing said second motor, and controllable means coupling the output of said second generator to still another control winding on said magnetic amplifier to control energization thereof and thereby control energization of the first generator and the first motor.

6. In an electric drive control system wherein the input to a generator is controlled by a multiple control winding magnetic amplifier to control operation of the motor energized from said generator and wherein a control winding of said magnetic amplifier receives its signal from said generator and another control winding receives its signal from a reference source, the improvement comprising a second motor coupled to the first motor for co-rotation therewith, a second generator for energizing said second motor, and means coupling said second generator to still another control winding on said magnetic amplifier, and operable to control energization of the last mentioned control winding and thereby control saturation of said magnetic amplifier, energization of the first generator, and energization of the first motor.

7. In an electric drive control system wherein the input to a generator is controlled by a multiple control winding magnetic amplifier to control operation of the motor energized from said generator and wherein a control winding of said magnetic amplifier receives its signal from said generator and another control winding receives its signal from a reference source, the improvement comprising a second motor coupled to the first motor for co-rotation therewith, a second generator for energizing said second motor, and means coupling said second generator to still another control winding on said magnetic amplifier, all of said control windings being additive during control of the first mentioned motor.

8. In an electric drive control system wherein the input to a generator is controlled by a multiple control winding magnetic amplifier to control operation of the motor energized from said generator and wherein a control winding of said magnetic amplifier receives its signal from said generator and another control winding receives its signal from a reference source, the improvement comprising a second motor coupled to the first motor for co-rotation therewith, a second generator for energizing said second motor, and means coupling said second generator to still another control winding on said magnetic amplifier, all of said control windings being additive during control of the first mentioned motor, and certain of said windings being subtractive when the motor is driven in a reverse direction by a load thereon.

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