CURRENT LIMITING IN THE WINDINGS OF ELECTROMAGNETIC DEVICES

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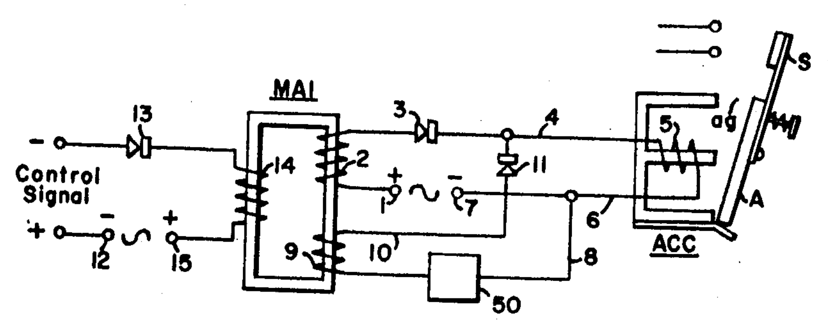
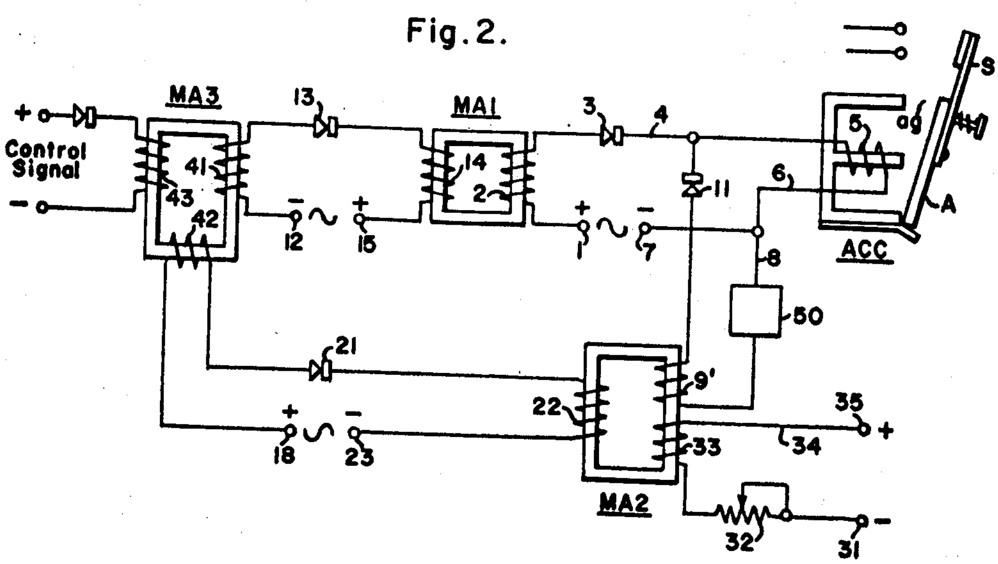


Fig.1.

Fig.2.



WITNESSES

Edwin E. Bassler

Leon M. Garman

INVENTORS
Richard O. Decker &
Werner Leonhard
BY
Paul E. Friedemann
ATTORNEY

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CURRENT LIMITING IN THE WINDINGS OF ELECTROMAGNETIC DEVICES

Richard O. Decker, Murrysville, and Werner Leonhard, Edgewood, Pa., assignors to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

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Our invention relates to an electromagnetic control system, and, more particularly, to a system for limiting the current in the winding, or coil, of an electromagnetic device designed to be energized with alternating current but in use is being supplied with a direct current, or at least one having a large direct-current component.

The coil of a solenoid operated valve, solenoid actuated clutch, designed to be normally operated from a source of alternating current, or the coil of an alternating-current contactor, each represents an impedance highly dependent on the position of the armature, or other movable part with reference to the other parts of the magnetic circuit involved. In a contactor, for example, in open conditions the impedance is small, but the impedance increases rapidly as the armature moves from its unactuated position to its fully actuated position. That is, the impedance increases with a decrease of the air gap in the magnetic circuit with the inductance being a maximum when the air gap is closed. When such a device is operated from a "stiff" alternating-current voltage source, the contactor takes a high current surge which produces enough force to pull the contactor in even though the air gap is large. As soon as the air gap closes, the impedance increases rapidly and in consequence the current is reduced to a safe value, sufficient to hold the contactor in.

This inherent current limiting characteristic which allows an economical design, is the distinguishing feature between alternating-current and direct-current contactors.

With the extensive use of magnetic amplifiers in control circuits, having half wave rectified direct current output alternating-current contactors are at times connected in the output circuit of the magnetic amplifier. If an alternating-current coil is thus energized from a magnetic amplifier, namely, a magnetic amplifier having a half-wave direct-current output, then the coil has to be redesigned, which is impractical, or some other means have to be provided, as current limiting resistors cut in by extra relays or auxiliary contacts on the contactor.

One broad object of our invention is the provision of static means for limiting the current in an inductive load when energized with a direct current.

Another broad object of our invention is the provision of controlling the output of a magnetic amplifier supplying an inductive load as a function of the impedance of the load.

These objects here stated are merely illustrative. Other objects and advantages will become more apparent from a study of the following specification, and the accompanying drawing, in which:

Figure 1 is a diagrammatic showing of the simplest embodiment of our invention; and

Figure 2 is a somewhat more elaborate diagrammatic showing of our invention.

In Fig. 1, a generally conventional alternating-current contactor, ACC, is shown connected in the output circuit of a substantially conventional half-wave magnetic amplifier MA1.

This invention is, however, not restricted in use to the

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particular type of half-wave magnetic amplifier which is herein shown. Other types of half-wave magnetic amplifiers may be used.

The contactor has a magnetic circuit including a movable armature A for actuating the switch S for closing a circuit in a portion of other control circuitry no part of this invention. The armature A is shown as spaced from the core member of the contactor with a considerable air gap *ag*. The actuating coil **5** is in the output circuit of the magnetic amplifier MA1.

The magnetic amplifier MA1 has the magnetic circuit shown. The magnetic circuit carries the control windings **9** and **14** and the main winding **2**. The main winding **2** is connected in a circuit that may be traced from the left-hand terminal **1** of a suitable source of single-phase alternating current, main winding **2**, rectifier **3**, poled as indicated, conductor **4**, armature actuating winding **5**, conductor **6** to the right-hand terminal **7** of the alternating-current supply.

The control winding **14** is connected in a circuit from alternating-current terminal **12**, rectifier **13**, poled as indicated, control winding **14** to the alternating-current terminal **15**. The alternating currents supplied to terminals **1** and **7**, and **12** and **15** are in phase with instant polarities as shown. The voltage on terminals **12** and **15** may be made variable, may be arranged to have a direct-current component of a selected value, or be of a direct current character of a selected value. Usually in this circuit, voltage between terminals **12** and **15** is a resetting voltage that is opposed by a control signal. For this arrangement, when there is no control signal, the voltage between terminals **12** and **15** resets the core during its resetting half cycle, which half cycle is the half cycle when terminal **12** is positive and when terminal **15** is negative, and during the following gating half cycle, when the polarities at terminal **12** and **15** are as shown in Fig. 1, substantially no current flows in the output circuit, namely, the circuit including the coil, or actuating winding **5**.

When a control signal is present, the voltage between terminals **12** and **15** is opposed during the resetting half cycle. The control signal must, of course, be of sufficient magnitude to block the rectifier **13** during the resetting half cycle. Therefore, no flux reset occurs and a heavy current will flow in coil **5** during the next half cycle, which half cycle is a gating half cycle. On the immediately subsequent resetting half cycle some current will flow in the circuit from conductor **6**, through conductor **8**, device **50** when used, conductor **10**, rectifier **11** poled as indicated, to conductor **4**. This current in control winding **9** will be small in comparison to the current that flows in control winding **9** in subsequent resetting half cycles after the contactor ACC pulls in. After the contactor ACC pulls in, a relatively heavy current flows in control winding **9** during the resetting half cycles. The reason for the current flow in winding **9** during the resetting half cycles is because of the inductive nature of the coil **5**. The current in winding **9** thus increases as the contactor pulls in. The winding relation of the control winding **9** with respect to the windings **2** and **14** is such that the ampere turns increase the resetting of the core of the magnetic amplifier MA1. This increased resetting reduces the output of the gating cycles. Since the magnitude of the current in coil **9** is here directly related to the position of the armature with respect to the stationary portion of the magnetic circuit, it is apparent we have provided a reliable, dependable, and self-adjusting current limiting feature for the coil **5**.

In Fig. 2, the magnetic amplifier MA1 functions as in Fig. 1 except that the control winding **14** of the magnetic amplifier is supplied by the output circuit of the magnetic amplifier MA3.

The contactor ACC is interconnected with a magnetic amplifier MA2 such that the feed-back circuit in parallel with coil **5** includes conductor **8**, device **50** when used, control winding **9'** on magnetic amplifier MA2, rectifier **11**, poled as indicated, to conductor **4**. The magnetic amplifier MA2 is also provided with a control winding **33** in the adjustable voltage circuit including negative terminal **31**, adjustable resistor **32**, control, or bias, winding **33**, and conductor **34** to the positive terminal **35**.

A more positive feed-back signal than obtained with the circuit shown in Fig. 1, can be obtained with the circuit arrangement shown in Fig. 2. The magnetic amplifier MA3 has main, or output, windings **41**, and control windings **42** and **43**. Winding **42** is the feedback winding receiving its signal from magnetic amplifier MA2. Here magnetic amplifier MA3 serves as a preamplifier for magnetic amplifier MA1. The polarities indicated in Fig. 2 for the terminals **12** and **15**, **1** and **7**, and **18** and **23**, are the instantaneous polarities for the resetting half cycle of magnetic amplifier MA3, for the gating half cycle of the magnetic amplifier MA1, and the gating half cycle of the magnetic amplifier MA2.

With no control signal present on winding **43**, magnetic amplifier MA3 has full output which acts to reset magnetic amplifier MA1 completely. In consequence, no current flows in output winding **2** of magnetic amplifier MA1. The feedback winding **42** on magnetic amplifier MA3 is so connected that a current in this winding opposes the effect of the control signal in winding **43**. A control signal of sufficient magnitude resets magnetic amplifier MA3 which then does not reset magnetic amplifier MA1 and current flows in the output circuit of magnetic amplifier MA1.

Magnetic amplifier MA2 may be so biased that it is cut off for all currents in control winding **9'** less than a selected value, namely for all current values present as long as the contactor ACC is open. With magnetic amplifier MA2 cut-off, no feedback signal is fed to magnetic amplifier MA3. When the contactor ACC closes and thus effects a higher inductance of coil **5**, heavy current flows in control winding **9'**.

The winding relation of winding **9'** with respect to windings **22** and **33** is such that the ampere turns decrease the resetting of the core of magnetic amplifier MA2.

When the output of magnetic amplifier MA2 increases, due to the decreased resetting current, current is supplied to the feedback winding **42** on magnetic amplifier MA3. This current in the feedback winding **42** opposes the control signal in winding **43** and increases the output voltage of magnetic amplifier MA3 and thus reduces the output voltage of magnetic amplifier MA1. The aim of protecting the coil **5** against unsafe current values is thus attained, while safely holding the armature A in actuated position.

When the control signal in winding **43** of magnetic amplifier MA3 is removed, the voltage output of magnetic amplifier is at full value and magnetic amplifier MA1 is substantially cut off. The contactor ACC thus drops out.

Either method of precedure, as shown in Fig. 1 or Fig. 2, however, gives a safe and efficient means of limiting the current in coil **5** after the contactor has operated. The result is that an alternating-current contactor can be operated from a half move source with a current limit scheme that does not require resistors and auxiliary contacts.

For some applications it is desirable to indicate the condition of the circuit including the coil **5**. The device **50** is shown interconnected with this circuit. The device **50** may be a meter, or signal light indicating whether or not contactor ACC has operated. The device **50** may also constitute control means for effecting operation of other circuitry depending on the operation of contactor ACC.

While we have shown and described but two embodiments of our invention, it is apparent that other modifications and arrangements are possible all falling within the spirit and scope of our invention.

We claim as our invention:

1. In an electric system of control, in combination, an inductive load the energization of which is to be controlled, said inductive load in use having a variable impedance, a magnetic amplifier having a magnetic circuit and having a main winding and two control windings, all of said windings being interlinked with the magnetic circuit, a rectifier, a pair of terminals in use energized with single-phase alternating current, a circuit including the main winding, the rectifier, and the inductive load connected across said terminals, means for so energizing one of the control windings to effect a selected effective degree of saturation of the magnetic circuit to thus energize the inductive load with pulsating direct current of a magnitude dependent on the selected effective degree of saturation of the magnetic circuit and the impedance of the inductive load, and means for energizing the second control winding as a function of the impedance of the inductive load to decreased the saturation of the magnetic circuit with a rise of the impedance of the inductive load.

2. In an electric system of control, in combination, an inductive load normally in use having the characteristic to rapidly increase its impedance upon energization with alternating current but the impedance of which rises less rapidly if energized with pulsating direct current, a magnetic amplifier in use suitably energized and having an output circuit for producing pulsating direct current, circuit means for connecting the inductive load to the output circuit of the magnetic amplifier, and control means responsive to the rise of impedance of the inductive load to decrease the output of the magnetic amplifier as a function of the rise of impedance of the inductive load.

3. In a system of control, in combination, an inductive load unit in use upon energization manifesting a rise in impedance, a magnetic amplifier having a magnetic core, a main winding on the core, and rectifier connected to energize the load unit from a suitable source of alternating current, a control winding for the magnetic amplifier so wound on the core to effect operation of the magnetic amplifier so as to energize the load unit, a second control winding for the magnetic amplifier, said second control winding being interconnected with the load unit and so disposed on the core to effect a decrease in the magnetic amplifier output with a rise in impedance of the load unit.

4. In a system of control, in combination, an inductive load unit in use upon energization manifesting a rise in impedance, a magnetic amplifier having a main winding and rectifier connected to energize the load unit from a suitable source of alternating current, a control winding for the magnetic amplifier to effect operation of the magnetic amplifier so as to effect energization of the load unit, a second control winding for the magnetic amplifier and a second rectifier, poled in opposition to the first rectifier, connected in series with the second control winding, said second control winding and second rectifier being connected in parallel with the load unit, the second control winding being so wound with respect to the other windings of the magnetic amplifier to decrease the output of the magnetic amplifier with a rise in impedance of the load unit.

5. In an electric system of control, in combination, an inductive load unit in use, upon initiation of its energization, manifesting a rise in impedance, a first magnetic amplifier having a main winding and rectifier connected in series therewith comprising the output circuit of the magnetic amplifier, said output circuit in use being connected to a suitable source of alternating current and being connected to energize the load units, said magnetic amplifier having a control winding for selecting the triggering point of the magnetic amplifier, and hav-

ing a second control winding for altering the output of the magnetic amplifier, a second magnetic amplifier having a main winding connected in series with a rectifier, the second control winding of the first magnetic amplifier and a suitable source of alternating current, said second magnetic amplifier having a bias winding for selecting its triggering point and having a second control winding and a rectifier connected in series therewith, this second control winding and series connected rectifier being connected in parallel with the load unit with this rectifier being poled in opposition to the poling of the rectifier in series with the main winding of the first magnetic amplifier.

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