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(54) **An arrangement for controlling the operation of switch contacts.**

(57) An arrangement for controlling the operation of switch contacts includes means for providing a first signal indicating that operation of the switch contacts is required and timing means arranged to provide a second signal at a time indicative of a zero crossing of an alternating voltage being switched by the switch contacts. Delay means are arranged to delay the second signal to compensate for the mechanical and/or electrical inertia of an operating means for the switch contacts. The operating means is then energised in response to the first and second signals so that operation of the switch contacts will occur at or near to a zero crossing of the alternating voltage.

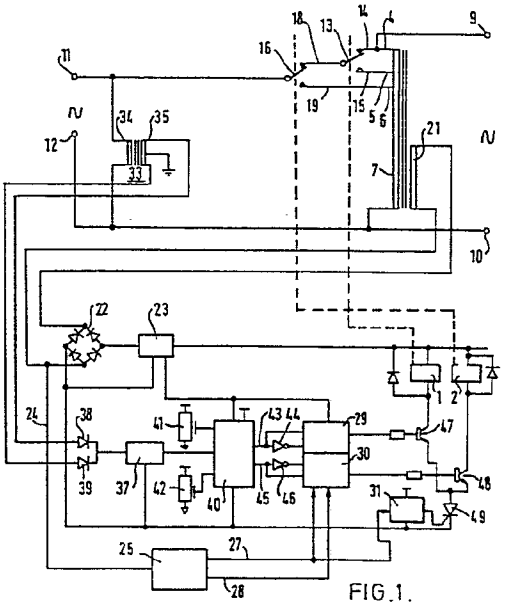

FIG.1.

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An arrangement for controlling the operation of switch contacts

TECHNICAL FIELD OF THE INVENTION

This invention relates to an arrangement for controlling the operation of switch contacts and has an important application in an arrangement for controlling the operation of switch contacts utilized for tap changing in the stabilization of a mains alternating current supply or utilized in the control of mains alternating current supplied to an electric motor forming part of a mains voltage stabilizer.

When switch contacts are utilized to supply alternating current to a load, for example in the tap changing arrangement referred to above, arcing or sparking will occur at the switch contacts each time the contacts "open" and "close", unless the opening and closing is coincident with a zero crossing point of the voltage wave form of the supply. Such arcing and sparking is disadvantageous in that not only does it result in the generation or radio frequency interference, but it also causes pitting of, and build-up of material on, the contact surfaces. Moreover, repeated failure to open and close the contacts at the zero crossing point of the voltage wave form may cause the distorted contacts to weld together so that they can no longer be operated.

BACKGROUND ART

When switch contacts are utilized for tap changing in the stabilization of a mains alternating current supply they usually take the form of assemblies of electromagnetically operated relays arranged to open and close their associated contacts in selected combinations to vary the tapping points in accordance with variations in the supply voltage. In order to ensure that the relay contacts open and close at or near a zero crossing point it has been proposed to select relays with operating characteristics such that the delays in the opening and closing of the contacts, as a result of energisation and the de-energisation

of the relay windings, are such as to bring about the desired result. It has also been proposed to bend the relay contacts from their normal positions in an endeavour to adjust the opening and closing times so that they more nearly approach a zero crossing of the voltage wave form.

The selection of relays with suitable operating characteristics may not be entirely satisfactory since the operating tolerances within a given batch of supposedly similar relays may vary widely. Moreover, the adjustment by bending of the contacts is somewhat empirical and may fail to achieve the desired object since the bends in the contacts tend to straighten out with repeated use.

An object of the invention is to provide an arrangement for controlling the operation of switch contacts which alleviates the above-mentioned disadvantages.

DISCLOSURE OF THE INVENTION

According to the present invention an arrangement for controlling the operation of switch contacts comprises means for providing a first signal indicating that operation of the switch contacts is required, timing means arranged to provide a second signal at a time indicative of a zero crossing of an alternating voltage being switched by the switch contacts, and delay means arranged to delay the second signal to compensate for mechanical and/or electrical inertia of an operating means for the switch contacts, and means for energising the operating means in response to the first and second signals so that operation of the switch contacts will occur at or near toa zero crossing of the alternating voltage.

In one embodiment of the invention the switch contacts are utilized for tap changing in the stabilization of a mains voltage supply, and the means for providing the first signal indicating that operation of the switch contacts is required comprises an arrangement for monitoring the fluctuations in the mains supply voltage.

In the above embodiment of the invention the arrangement for monitoring the fluctuations in the mains voltage supply comprises comparison means arranged to produce one or more signals each indicative of an increase or a decrease in the main supply voltage relative to a reference voltage.

When the switch contacts are utilized for tap changing they may be arranged in either the input side or the output side of a transformer.

In another embodiment of the invention the switch contacts are utilized to vary the sense of the current applied to an electric motor driving a continuously variable tapping on a transformer, and the means for providing the first signal indicating that operation of the switch contacts is required comprises an arrangement for monitoring the fluctuations in the output voltage of the transformer.

In this other embodiment the arrangement for monitoring the fluctuations in the output voltage of the transformer comprises comparison means arranged to produce one or more signals indicative of an increase or a decrease in the output voltage of the transformer relative to a reference voltage.

The delay means may be arranged to provide delays of different durations depending on whether the operating means is to be energised or de-energised.

The operating means may be the operating winding of an electromagnetic relay and the switch contacts the relay contacts.

The operating winding of the relay may be energised by a transistor arranged to be turned on and off in response to the first and second signals.

The timing means may comprise rectifying means arranged to sample the alternating voltage and to provide a second signal at each zero crossing point of the alternating voltage.

Some embodiments of the invention will now be described, by way of example with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block schematic circuit diagram of a control arrangement in accordance with the invention having switch contacts adapted for tap changing in the stabilization of a mains alternating current supply.

Figure 2 is a more detailed circuit diagram of the control arrangement shown in Figure 1;

Figure 3 is a block schematic circuit diagram of a control arrangement in accordance with the invention having switch contacts adapted to vary the sense of the current applied to an electric motor driving a continuously variable tapping on a transformer; and

Figure 4 is a modification of the control arrangement shown in Figure 3.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring in the first instance to Figure 1, the control arrangement comprises two electromagnetically operated relays 1 and 2 which are arranged to select tapping points 4, 5 and 6 on an auto transformer 7 so as to provide a stabilized output voltage at output terminals 9 and 10 despite fluctuations in a mains input voltage applied to input terminals 11 and 12. The relay 1 has changeover contacts comprising a movable ccontact 13 and fixed contacts 14 and 15 connected respectively to tapping points 4 and 5. The relay 2 has a movable contact 16 connected to input terminal 11 and fixed contacts 18 and 19 connected respectively to the movable contact 13 and the tapping point 6.

A winding 21 inductively coupled to the auto transformer 7 is arranged to apply a 30 volt alternating current supply to a full wave rectifier 22 arranged to feed a stabilized power supply 23 providing a 24 volt D.C. supply voltage. A lead 24 connected to one side of winding 21 supplies an alternating voltage to a timing and delay circuit 25 which rectifies the alternating voltage and provides a timing signal indicative of each zero crossing of the voltage wave form of the mains alternating current applied to input terminals 11 and 12. The timing and delay circuit 25 is arranged to delay the timing signal by an amount corresponding to the mechanical and electrical inertia of the electromagnetic relays 1 and 2.

In a typical electromagnetic relay suitable for the present tap changing arrangement, the mechanical inertia of the armature and contacts and the electrical inertia due to the inductance of the relay winding amount to substantially 8 milliseconds when the typical relay is being energised and amount to substantially 5 milliseconds when the typical relay is being de-energised. For this reason the timing and delay delay circuit 25 is arranged to provide two delayed timing signals respectively on output leads 27 and 28 which are connected to two latch circuits 29 and 30. The output lead 27 is also connected to a start circuit 31 to apply the delayed timing signal thereto for a purpose to be described later.

A transformer 33 having a primary winding 34 connected across the input terminals 11 and 12 also has a centre tapped secondary winding 35 connected to a mains voltage sampler 37 by way of two diodes 38 and 39. The output from the mains voltage sampler 37 is applied to a dual comparator 40 which compares the sampled mains voltage with two stabilized reference voltages provided respectively by reference voltage circuits 41 and 42. The dual comparator 40 and the latch circuits 29 and 30 are energised from the stabilized D.C. power supply 23. The dual comparator 40 is provided with an output lead 43 connected to a SET input of latch circuit 29 directly and

to a RESET input of latch circuit 29 by way of an inverter 44. The dual comparator 40 is also provided with a further output lead 45 connected to a RESET input of latch circuit 30 directly and to a SET input of latch circuit 30 by way of an inverter 46. The output of latch circuit 29 is connected to the base of a transistor 47 arranged to energise the relay 1 from the D.C. power supply 23 while the output of latch circuit 30 is connected to the base of a transistor 48 arranged to energise the relay 2 from the D.C. supply 23. The output of the start circuit 31 is connected to the trigger electrode of a silicon controlled rectifier 49 which is connected to the emitter electrodes of the transistors 47 and 48.

The control arrangement shown in Figure 1 operates in the manner described below to effect operation of the switch contacts at or near to a zero crossing point of the mains alternating voltage whenever fluctuations of the mains voltage applied to input terminals 11 and 12 occur. When the mains voltage is between the reference voltages of reference voltage circuits 41 and 42 the output signals provided by the dual comparator 40 on output leads 43 and 45 are both in a logic "high" state. If the mains voltage falls below the low reference voltage of reference voltage circuit 41 or rises above the high reference voltage of reference voltage circuit 42 the relevant output changes to the logic "low" state. Thus if the mains voltage rises above the high reference voltage of reference voltage circuit 42, the output signal provided by dual comparator 40 on output lead 43 goes to a logic "low" state. This RESETS the normally set latch circuit 29 which provides an output signal at the instant that an input signal from the delay circuit 25 is received on lead 28. This output signal from latch circuit 29 turns off transistor 47 thus releasing relay 1 so that tapping point 4 is selected by movable contact 13 at the zero crossing point. This is the position of the contacts 13, 14, 15, 16, 18 and 19 illustrated in the drawing.

If the mains voltage now falls to a value between the two reference voltages of reference voltage circuits 41 and 42 the output signal on output lead 43 goes to a "high" logic state and SETS the latch circuit 29 which provides an output signal at the instant that a signal from delay circuit 25 is received on lead 27. This output signal from the latch circuit 29 turns on the transistor 47 thus operating relay 1 so that tapping point 5 is selected by movable contact 13 at the zero crossing point.

If the voltage then falls to a value below the low reference voltage of reference voltage circuit 41 the output signal provided by the dual comparator 40 on output lead 45 goes to a logic "low" state. This SETS the latch circuit 30 which provides an output signal at the instant that an input signal from the delay circuit 25 is received on lead 28. This output signal from the latch circuit 30 turns on transistor 48 thus energising relay 2 so that tapping point 6 is selected by movable contact 16 at the zero crossing point.

In order to avoid "chatter" of the contacts 13, 14, 15, 16, 18 and 19 when the circuit is first switched on, the transistors 47 and 48 are prevented from being turned until after a delay determined by the start circuit 31. This gives the control arrangement time to "warm up" and become fully operational. To this end the start circuit is arranged to trigger the silicon controlled rectifier 49 in the emitter/collector circuits of both the transistors 47 and 48. Moreover, the signal provided by the delay circuit 25 on lead 27 ensures that the initial closing of the relay contacts takes place at a zero crossing point.

Referring now to Figure 2 in which the same reference numerals as those used in Figure 1 have been used to denote similar parts or assemblies of components forming such parts. As before the switch contacts 13, 14, 15, 16, 18 and 19 are changeover contacts of two relays 1 and 2 arranged to select tapping points on an auto transformer 7 to provide a stabilized output voltage at output terminals 9 and 10.

The transformer 33 again has a secondary winding 35 feeding a mains voltage sampler 37 by way of two diodes 38 and 39. The assembly of components forming the mains voltage sampler 37 includes three resistors 51, 52 and 53 and two capacitors 54 and 55. The dual comparator 40 is formed by an integrated circuit in the form of a "window discriminator" which compares the sampled mains voltage with the two reference voltages provided respectively by reference voltage circuits 41 and 42.

The assembly of components forming the delay circuit 25 includes two resistors 57 and 58 which provide charging current for a capacitor 59. A ramp signal is produced across capacitor 59 by two resistors 61 and 62 and a diode 63 which remove the charge from capacitor 59 at each zero crossing of the mains alternating voltage. The ramp signal is supplied to the input of a schmitt trigger circuit formed by two resistors 65 and 66 and two inverters 67 and 68 connected in cascade, the ratio of the two resistors 67 and 68 providing positive feedback. When the ramp signal across capacitor 59 has charged to approximately 5.9 volts the schmitt circuit will trigger with the output of inverter 68 going positive to 12 volts. Resistors 65 and 67 provide hysteresis so that the schmitt circuit will not reset until the voltage across capacitor 59 has fallen to approximately 5.1 volts. A similar schmitt trigger circuit is provided by resistors 70 and 71 and inverters 72 and 73 except that the ramp signal may be set to a larger amplitude by a resistor 74.

The latch circuit 29 has an assembly of components including two capacitors 76 and 77 and two resistors 78 and 79 feeding two NOR gates 80 and 81 arranged to turn on and off the transistor 48 which supplies energising current to relay 2. Similarly the latch circuit 30 has an assembly of components including two capacitors 83 and 84 and two resistors 85 and 86 feeding two NOR gates 87 and 88 arranged to turn on and off the transistor 47 which supplies energising current to relay 1.

The operation of the control arrangement is similar to that described with reference to Figure 1 in that the contacts 13, 14, 15, 16, 18 and 19 are only operated in response to signals generated by the comparator 40 after a delay produced by the delay circuit 25 which ensures that tap changing by the contacts is coincident with a zero crossing of the mains voltage wave form. The delay circuit 25 again provides two delayed timing signals which compensate for both the mechanical and electrical inertia of the relays 1 and 2, one delayed signal being for the inertia during energisation and "pull in" of a relay 1 or 2 and the other delayed signal being for the inertia during de-energisation and "drop out" of a relay 1 or 2. The delays may be adjusted to suit the operating characteristics of particular relays 1 and 2. Moreover, a start circuit 31 which includes two resistors 90 and 91, a diode 92 and a capacitor 93 ensures that the control arrangement has time to warm up when first switched on before it becomes fully operative, and that the initial closing of the contacts will occur at a zero crossing point.

Although the arrangement described above has relatively simple combinations of switching contacts involving only two sets of changeover contacts, it will be appreciated that other embodiments of the invention may have more complex "trees" of switch contacts with correspondingly large numbers of tapping points. Moreover, although in the illustrated arrangements the contacts are arranged in the input side of the transformer they could equally well be arranged on the output side. A single relay having contacts controlling two tapping points could also be used.

Turning now to Figure 3, the control arrangement comprises two electromagnetically operated relays 101 and 102 arranged to reverse the direction of the energising current through

an electric motor 103 depending on whether an alternating output voltage developed at output terminals 104 and 105 of an auto-transformer 106 is rising or falling. One side of the energising winding 107 of the electric motor 103 is connected to the output terminal 104 by way of a fixed contact 108 and a movable contact 109 of the relay 102. The other side of the winding 107 is connected to the output terminal 104 by way of a fixed contact 110 and a movable contact 111 of the relay 101. The winding 107 is shunted by a capacitor 112. The electric motor 113 is arranged to drive a continuously variable tapping point 114 on the transformer 106 which is supplied with mains alternating voltage by way of input terminals 115 and 116.

A transformer 117 has its primary winding 118 connected across output terminals 104 and 105 and has its secondary winding arranged to apply a 30 volt alternating current supply to a full wave rectifier 22 arranged to feed a stabilized power supply 23 providing a 24 volt D.C. supply voltage. A lead 24 connected to one side of winding 119 supplies an alternating voltage to the timing and delay circuit 25 which rectifies the alternating voltage and provides a timing signal indicative of each zero crossing of the mains alternating voltage developed acorss output terminals 104 and 105. The timing and delay circuit 25 is arranged to delay the timing signal by an amount corresponding to the mechanical and electrical inertia of the electromagnetic relays 101 and 102.

The primary winding 118 of the transformer 117 is connected to a mains voltage sampler 37 by way of two diodes 38 and 39. As before the output from the mains voltage sampler 37 is applied to a dual comparator 40 which compares the sampled mains voltage with two stabilized reference voltages provided respectively by reference voltage circuits 41 and 42. The dual comparator 40 is provided with an output lead 43 connected

to a SET input of latch circuit 29 directly and to a RESET input of latch circuit 29 by way of an inverter 44. The dual comparator 40 is also provided with a further output lead 45 connected to a RESET input of latch circuit directly and to a SET input of latch circuit 30 by way of an inverter 46. As before the output of latch circuit 29 is connected to the base of a transister 47 arranged to energise the relay 101 while the output of latch circuit 30 is connected to the base of a transister 48 arranged to energise the relay 102. The output of the start circuit 31 is connected to the trigger electrode of a silicon controlled rectifier 49 which is connected to the emitter electrodes of the transisters 47 and 48.

The control arrangement shown in Figure 3 operates in the manner described below to effect operation of the relay contacts 108, 109, 110 and 111 at zero crossing points of the mains alternating voltage, whenever the mains output voltage at output terminals 104 and 105 fluctuates above or below the reference voltages of reference voltage circuits 41 and 42. When the voltage across output terminals 104 and 105 is above the reference voltage of reference voltage circuit 42 the relay 101 is energised to close contacts 110 and 111 and drive the electric motor so that the variable tapping points 114 is moved in a direction such as to reduce the output voltage. The delay produced by the timing and delay circuit 25 ensures that the operation of the contacts 110 and 111 is coincident with a zero crossing point of the mains voltage wave form.

When the voltage across output terminals 104 and 105 falls below the reference voltage of reference voltage circuit 42 the relay 101 is de-energised so that contacts 110 and 111 are opened and energising current is no longer supplied to the electric motor 103 which stops. The timing and delay circuit 25 provides a delay which ensures that the opening

of the contacts 110 and 111 is coincident with a zero crossing of the voltage wave form.

If now the alternating voltage across output terminals 104 and 105 falls below the reference voltage of reference voltage circuit 41, relay 102 is energised to close contacts 108 and 109 and drive the electric motor in the reverse direction, to move the variable tapping point 114 in a direction such as to raise the voltage at output terminals 104 and 105. The delay provided by the timing and delay circuit 25 is such as to ensure that the closing of the contacts 108 and 109 is coincident with a zero crossing of the mains voltage wave form.

When the voltage at output terminals 104 and 105 rises above the reference voltage of reference voltage circuit 41 the relay 102 is de-energised so that contacts 108 and 109 are opened and the electric motor 103 is de-energised. The delay produced by the timing and delay circuit 25 is such as to ensure that the opening of the contacts 108 and 109 is coincident with a zero crossing of the mains voltage wave form. As before the start circuit 31 ensures that the control arrangement has time to warm up when first switched on before it becomes fully operative so that the initial closing of the contacts of either of the relays 101 and 102 will take place at a zero crossing point.

Turning finally to the modified arrangement shown in Figure 4, the transformer 106 is connected across the output terminals 104 and 105 and is coupled to the input terminals 115 and 116 by way of a buck/boost transformer 121. One end of the secondary winding of the transformer 121 is connected to a fixed tapping point 124 on the transformer 106 while the other end of the secondary winding 122 is connected to a continuously variable tapping point 125. As before the electric motor is arranged to drive the tapping point 125 in a manner such

as to stabilize the output voltage at terminals 104 and 105. As before the delay produced by the timing and delay circuit 25 is such as to ensure that whenever the relays 101 and 102 are energised or de-energised the resultant opening and closing of their associated contacts 108, 109, 110 and 111 will always take place at a zero crossing of the alternating voltage.

As a practical matter it has been found that with a 50 Hz mains alternating current supply the operation of the arrangement of the invention is satisfactory if the contacts operate within 2 milliseconds on either side of the zero crossing point of the alternating voltage and gives excellent results if the contacts operate within one millisecond on either side of the zero crossing point of the alternating voltage.

CLAIMS

1. An arrangement for controlling the operation of switch contacts comprising means for providing a first signal indicating that operation of the switch contacts is required, timing means arranged to provide a second signal at a time indicative of a zero crossing of an alternating voltage being switched by the switch contacts, and delay means arranged to delay the second signal to compensate for mechanical and/or electrical inertia of an operating means for the switch contacts, and means for energising the operating means in response to the first and second signals so that operation of the switch contacts will occur at or near to a zero crossing of the alternating voltage.

2. An arrangement as claimed in Claim 1, wherein the switch contacts are utilized for tap changing in the stabilization of a mains voltage supply and the means for providing the first signal indicating that operation of the switch contacts is required comprises an arrangement for monitoring the fluctuations in the mains supply voltage.

3. An arrangement as claimed in Claim 2, wherein the arrangement for monitoring the fluctuations in the mains voltage supply comprises comparison means arranged to produce one or more signals each indicative of an increase or a decrease in the main supply voltage relative to a reference voltage.

4. An arrangement as claimed in Claim 2 or Claim 3, wherein the switch contacts utilized for tap changing are arranged in the input side of a transformer.

5. An arrangement as claimed in Claim 2 or Claim 3 wherein the switch contacts utilized for tap changing are arranged in the output side of the transformer.

6. An arrangement as claimed in Claim 1, wherein the switch contacts are utilized to vary the sense of the current applied to an electric motor driving a continuously variable tapping on a transformer, and the means for providing the first signal indicating that operation of the switch contacts is required comprises an arrangement for monitoring the fluctuations in the output voltage of the transformer.

7. An arrangement as claimed in Claim 6, wherein the arrangement for monitoring the fluctuations in the output voltage of the transformer comprises comparison means arranged to produce one or more signals indicative of an increase or a decrease in the output voltage of the transformer relative to a reference voltage.

8. An arrangement as claimed in any preceding claim, wherein the delay means is arranged to provide delays of different durations depending on whether the operating means is to be energised or de-energised.

9. An arrangement as claimed in any preceding claim, wherein the operating means is the operating winding of an electromagnetic relay and the switch contacts are the relay contacts.

10. An arrangement as claimed in Claim 9, wherein the operating winding of the relay is energised by a transistor arranged to be turned on and off in response to the first and second signals.

11. An arrangement as claimed in any preceding claim, wherein the timing means comprises rectifying means arranged to sample the alternating voltage and to provide a second signal at

each zero crossing point of the alternating voltage.

12. An arrangement as claimed in any preceding claim, wherein the delay produced by the delay is such that the switch contacts operate within a period of two milliseconds on either side of the zero crossing point of the alternating voltage.

13. An arrangement as claimed in any preceding claim, including further delay means which ensures that there is a predetermined warm up time before the arrangement becomes fully operative, and that the first closing of a switch contact occurs at a zero crossing point of the alternating voltage.

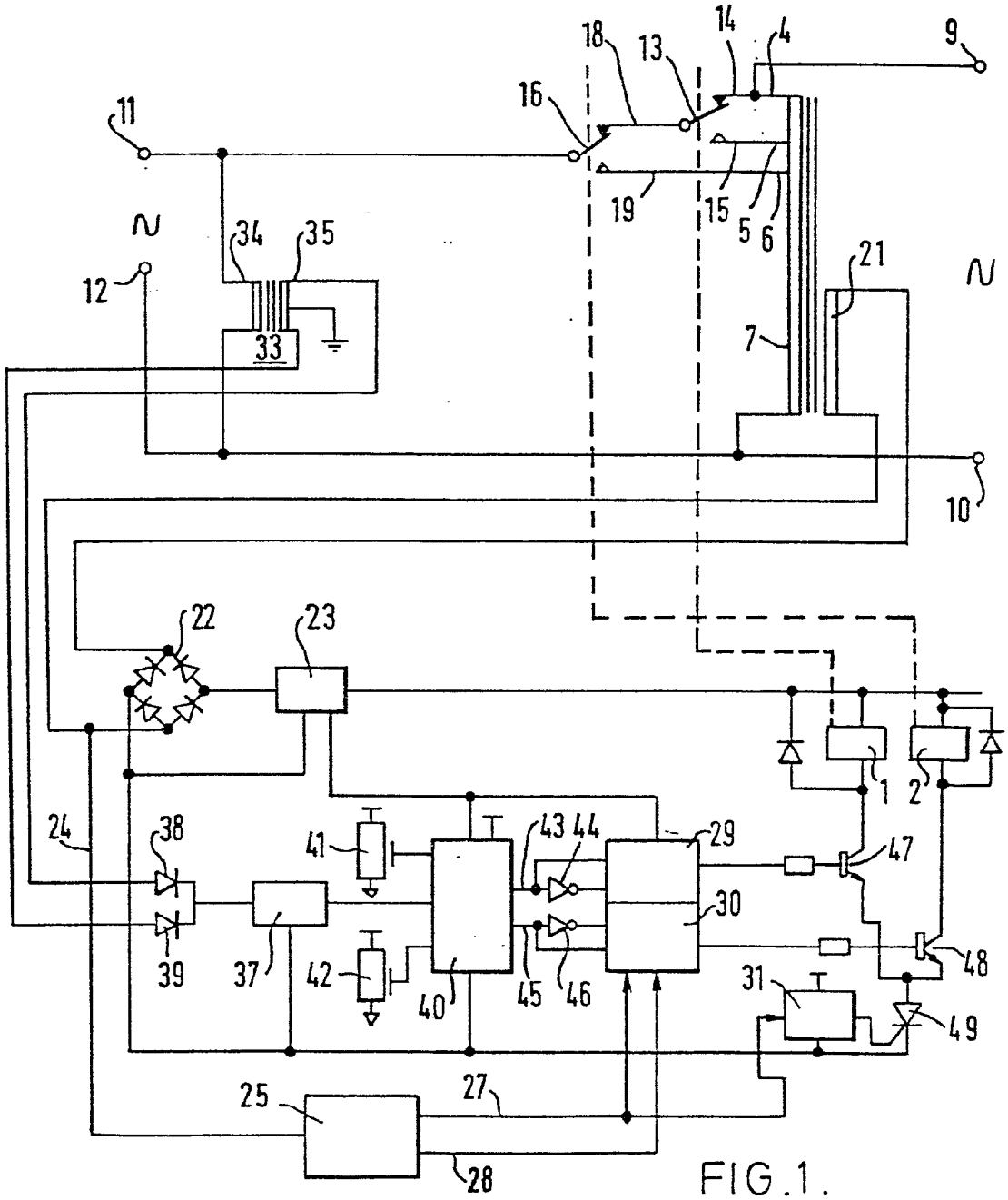
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FIG.1.

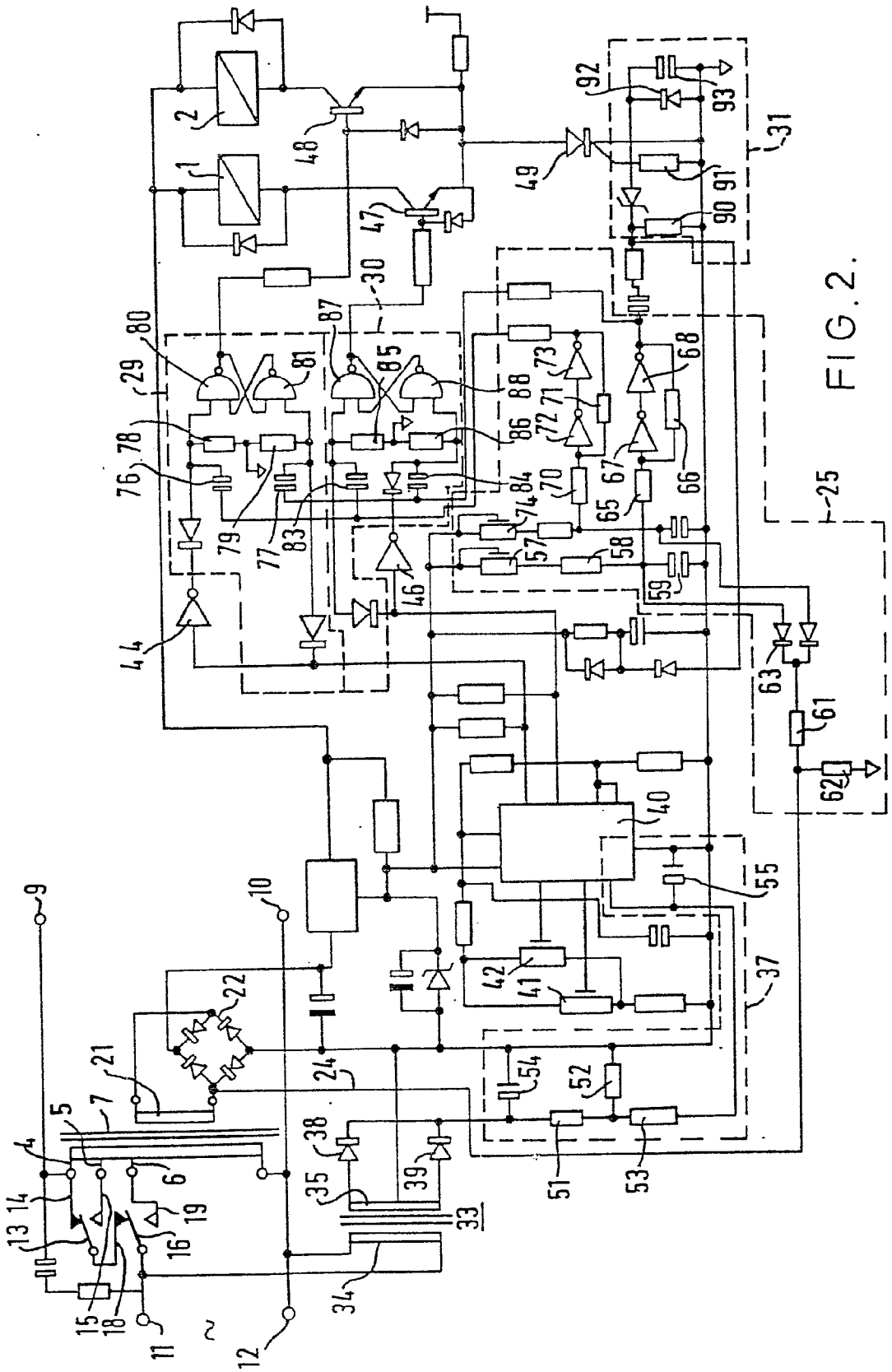

FIG. 2.

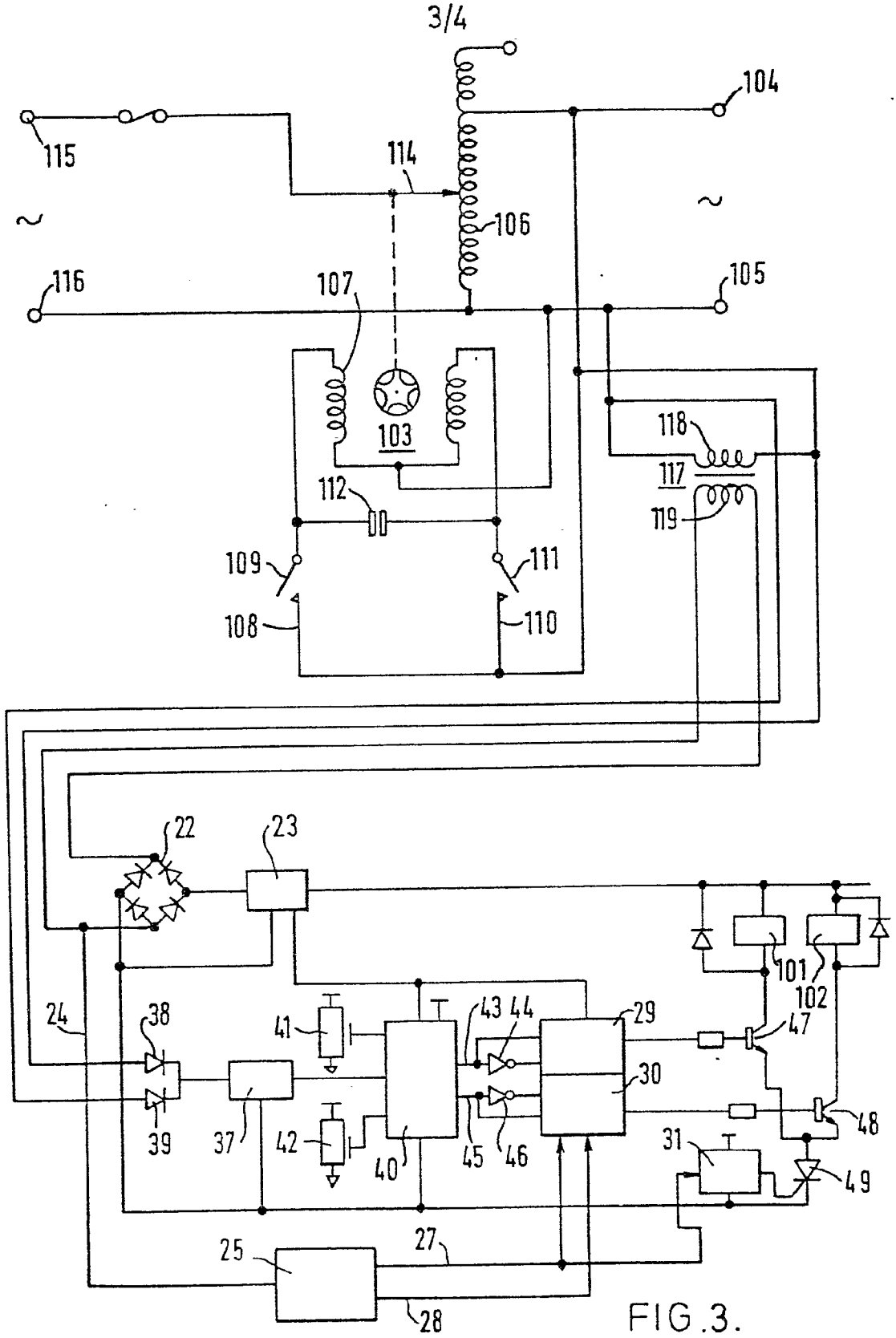
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FIG.3.

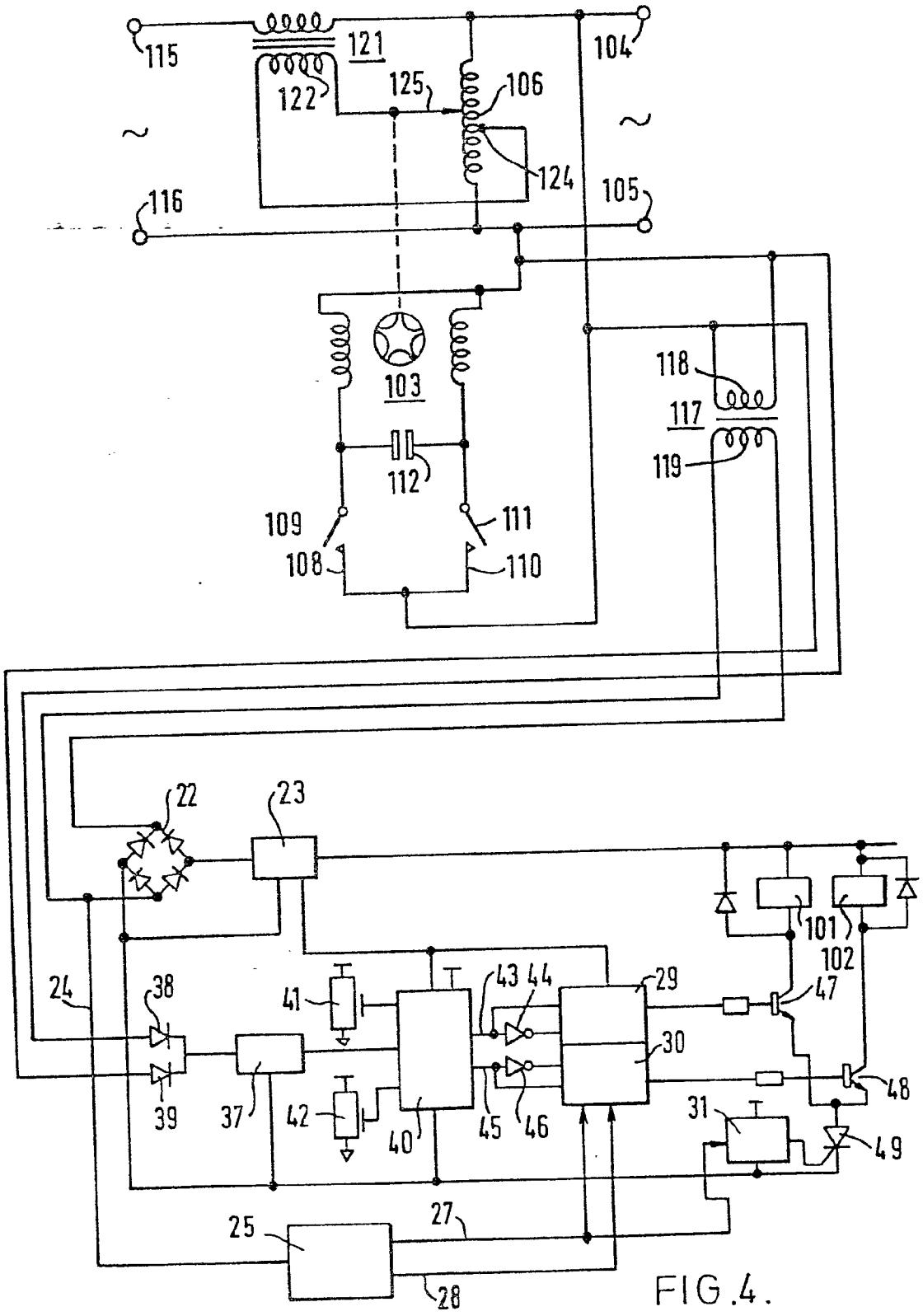
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FIG.4.