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(54) **Programmable system for stabilising and regulating voltage in particular for the improved management of lighting units using fluorescent bulbs and like**

(57) Programmable alternating voltage stabiliser/regulator system for feeding a load, in particular consisting of fluorescent bulbs, wherein the selective connection, even with powered load [through electromagnetic selection relays (30,31) and by-pass relays (73) and with the intermediary of an inverter switch (32)], of two from M+N taps of an autotransformer (19) or of the same tap, to the primary of a regulating transformer (29), with the secondary in series with the load, allows the feed voltage of the load to be corrected with an increase or decrease chosen between M(N+1) discreet and uniformly distributed values, lying between a zero minimum and a maximum.

Circuits (50,56,57,59,60,62,63) are also foreseen for the direct detection, at the operative contacts, of the state of the relays and thus to subordinate the execution of tap selection switching procedures to the correct and verified development of the various steps.

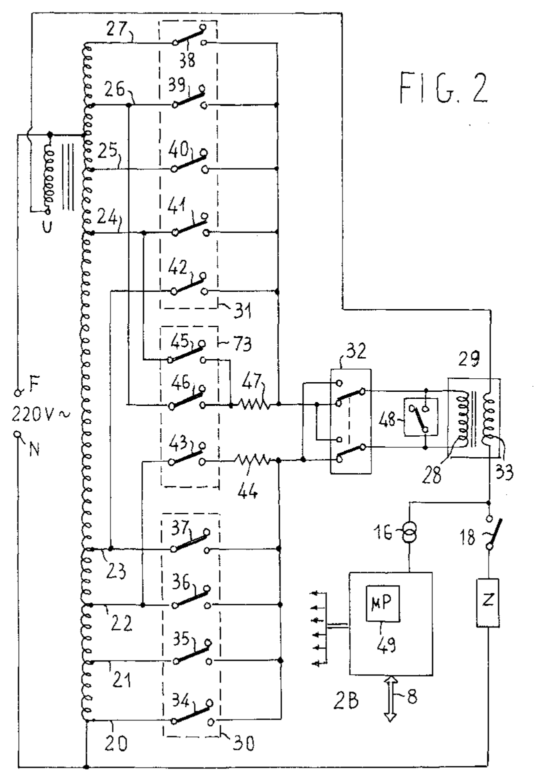

FIG. 2

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Description

[0001] The present invention regards a programmable system for stabilising and regulating voltage, in particular for the improved management of lighting units using fluorescent bulbs and more generally those of the gas discharge type.

[0002] It is known that this type of bulb, to be switched on, requires a predetermined ignition voltage and that, when it has been switched on, after a period of heating which depends, amongst other things, upon the environment temperature, the supply voltage can be substantially reduced, still being kept above a predetermined minimum, which is necessary to avoid the light turn off.

[0003] It is also known that the light flow of this type of bulb is not directly proportional to the supply voltage and to the power taken up and that the maximum lighting efficiency is obtained in a range of supply voltages lower than the voltage needed to switch it on.

[0004] In such a range the light flow can be regulated, by varying the supply voltage, to adapt it to the user's requirements.

[0005] Finally, it is known that the application of excessive voltages does not give a significant increase in the light flow and substantially reduce the useful life of the bulb.

[0006] Therefore, management systems have been designed which take care of supplying such types of bulb with a regulated voltage, obtained from the mains, modulated to carry out the switching on and the heating of the bulbs in optimal conditions, then reduced and kept constant, independently from variations in the mains voltage, to obtain a predetermined light flow (also variable in time according to suitable programs) in conditions of optimal efficiency.

[0007] An example of this type of system is provided by document EP0753986.

[0008] Basically, in these systems the regulated supply voltage of the lighting unit is obtained with an autotransformer with many taps, selectively connected to the output one at a time, through switches controlled from a control and supervision station. Even if the use of solid state switches has been proposed, for reasons of cost and of safety the use of electromagnetic relays is generally preferred.

[0009] The choice of this type of regulation has numerous advantages with respect to alternative solutions, like the use of variable coupling transformers or completely electronic regulators, but at the same time brings a plurality of problems to be tackled and solved.

[0010] First of all, the fine regulation of the output voltage requires, also by exploiting the known expedient of the reversing device, a high number of taps and of corresponding connection relays which it is desirable to reduce to the minimum.

[0011] Then the switching of the taps must be able to take place under load, to avoid the bulbs turn off. Therefore, by-pass circuits are necessary controlled by further relays to ensure the load supply during the switching transient of the taps.

[0012] Indeed, it is materially impossible to obtain a switching with electromagnetic relays which is rapid and at the same time synchronous with the transition to zero of the alternating current applied to the load.

[0013] The by-pass circuits must dissipate the minimum power possible and at the same time ensure a voltage near to and preferably within the voltages which are switched, without for this reason requiring the use of a number of by-pass relays equal to the number of tap switching relays.

[0014] Finally, to avoid short circuits and at the same time to ensure the load supply without gaps in voltage/current it is necessary to verify, with reliable control systems, the open and closed state of every switching device before carrying out switching operations which could cause a short circuit, with catastrophic effects on the apparatus.

[0015] These problems are solved by the system object of the present invention as defined in the claims.

[0016] The characteristics and advantages of the present invention will become clearer from the following description of a preferred embodiment, with reference to the attached drawings wherein:

- figure 1 is a block diagram of the whole of a system for the optimised management of a lighting unit and of equipment comprising many systems;
- figure 2 is a power module circuit diagram for the system of figure 1;
- figure 3 is a circuit diagram of the detector devices of the state of the electromagnetic switches of the power module;
- figure 4 is an exemplifying diagram of voltage/lighting which represents a preferred management method of the lighting in a tunnel with the equipment of figure 1;
- figure 5 is an electrical diagram of a preferred embodiment of a photoresistor based brightness sensor and an auxiliary A/D conversion module for the system and equipment of figure 1.

With reference to figure 1 the system essentially comprises a control unit 1, with a microprocessor, a power module 2, with power section 2A and control section 2B, and a visualisation and command module 3, with luminous indicators, display and keyboard.

[0017] Through a manual or remote control switch 4 and a magnetothermic protection switch 5 the alternating voltage of the mains, in the figures nominally 225 V, is applied to the system.

[0018] In the control unit 1 an AC/DC power supply feeder 7, connected to the mains through a transformer 6, supplies the control unit 1 and the control section 2B (through feed wires 80) with the required stabilised continuous service voltages (±5V, +12V). The feeding of the control section is thus subordinated to the prior feeding of the control unit 1 which can verify the presence of the correct service voltage value applied to section 2B before controlling its intervention.

[0019] The mains voltage, input to the power section 2A, is regulated so as to obtain in output a predetermined voltage value which is applied to a load Z, consisting of a bulb set, with the closing of an electromagnetic switch 18, controlled by the control unit 1.

[0020] The control unit 1 and the control section 2B communicate through a channel 8, with serial or parallel interface.

[0021] According to the switching commands received from the command module 3, of the room temperature detected by a sensor 9, and possibly of the external lighting conditions detected by a sensor 10 and transferred to the control unit through an auxiliary module 130, the control unit 1 instructs the control section 2B so that the voltage to be applied to the load takes on an appropriate value, for switching on, heating and maintaining such as to ensure a predetermined level of lighting, detected by a sensor 11.

[0022] For safety the different sensors and the possible auxiliary module are electrically decoupled from the control unit, both in terms of the power supply and in terms of the output signal, transmitted to the control unit 1 through optoelectronic devices 12,13,14.

[0023] The control section 2B, as a function of the actual mains voltage, measured through a measuring transformer 15, and of the desired output voltage value, commands the power section to regulate the output voltage to the desired value and it controls it by means of a measuring transformer 16 which ensures the necessary feedback.

[0024] It also ensures, through a transformer 17, that the current and therefore the power absorbed does not exceed predetermined values beyond which it is necessary to activate the ventilation system and, at worst, to shut down the system. An inner overheating protector, not illustrated, can also be foreseen.

[0025] Although it is "intelligent", section 2B operates as a slave to the commands of the control unit 1, to which all the necessary information is transferred.

[0026] Although it is not illustrated in figure 1, it is clear that the control unit 1 can be, and in general is, also equipped with communication interfaces (modem and/or serial ports) to receive commands or transmit data to a remote supervision centre.

[0027] It must be noted that in regulation systems fed by a three-phase network three identical power modules can be present, controlled by a common control unit 1 through the channel 8 (in this case a BUS)or channels dedicated to and possibly provided with many sensors, to independently monitor the state of three distinct lighting sets.

[0028] For this, as well as the power module 2, two further modules 102, 103, identical to module 2 and obviously fed by the other two phases of the network, respectively, are represented in figure 1.

[0029] Other aspects of figure 1 shall be considered further on.

[0030] Figure 2 represents the structure of the power module 2A, 2B of figure 1 in greater detail, wherein the main (even if not exclusive) innovative aspects of the present invention are actually to be found.

[0031] The power module comprises an inlet autotransformer 19 with inlet terminals N (neutral) and F (phase) to which the mains voltage, for example with a nominal value of 225 V, is applied.

[0032] The autotransformer is equipped with an output terminal U to supply a load with a somewhat reduced nominal voltage equal to about 200 V which defines the average value of the regulation range in which the output voltage can be varied.

[0033] It is also equipped with a first group of M taps referenced in order as 20,21,22 (four in the represented preferred embodiment) upon which is available a nominal voltage referred to the neutral feeding potential equal to 0, 15, 30 and 45 V, respectively.

[0034] The autotransformer is further equipped with a second group of N taps referenced in order as 24,25,26,27 (four in the preferred embodiment) upon which is available a nominal voltage, referred to the neutral potential, equal to 105,165,225,285V, respectively.

[0035] It should immediately be noted that the voltage between adjacent taps of the first group is nominally equal to 15V whereas the voltage between adjacent taps of the second group, as well as between the tap of the second group adjacent to the tap of the first group, is equal to M • 15V, that is 60 nominal volts.

[0036] In other words and more generally, if the taps of the first group are electrically spaced out on the winding of the autotransformer by K turns, the taps of the second group are electrically spaced out by M • K turns, as are the electrically adjacent taps 24 and 23 of the first and of the second group respectively.

[0037] It is therefore clear that by selectively connecting a tap of the first group and a tap of the second group, or else two taps of the first group, to the terminals of a load of the first group, it is possible to feed the load with a discreet voltage which can be varied in multiples of 15V, between a minimum of 15 nominal volts and a maximum of 285 nominal volts.

[0038] Finally, by connecting the load terminals to the same tap, and from this point of view it does not matter which, it is possible to apply a zero voltage to the load.

[0039] Therefore with only M+N taps it is possible to apply to the load any of M • (N+1) distinct alternate voltages, of which one is zero.

[0040] It is clear that significant advantages with respect to the known solutions are only provided by M and N >2 and preferably with M=N.

[0041] In figure 2 the voltages available at the M+N output taps are selectively connected to the primary 28 of a voltage reducing auxiliary transformer 29, conveniently but not necessarily with a turn ratio close to 1/7, by means of two groups of electromagnetic switches 30, 31 and through a DPDT (Double Pole Double Throw) relay 32 with the function of reversing switch.

[0042] The secondary 33 of the transformer 29 is connected in series between the output terminal U of the autotransformer and the switch 18 for connecting to the load Z.

[0043] Therefore, it is clear that to the load Z can be applied a base voltage (200 nominal volts present at terminal U) increased or decreased (according to the closing position of the switch 32) by the voltage induced in the secondary 33 which varies from 0 to 285/7 V, that is about 40.7 V, in steps of about 2.1 nominal volts.

[0044] The (nominal) range of variability of the regulated feed voltage of the load thus extends from about 159V to about 241V, which is more than sufficient to ensure an effective and regulated output voltage of between 175 and 215V also in the case of variations in the mains voltage of up to ± 10% of the nominal voltage.

[0045] The first group 30 of electromagnetic switches, of the SPDT type, comprises M (M=4) relays 34,35,36,37 with the common pole connected to the sockets 20,21,22,23 respectively of the first group and the normally open contact(that is with the relay de-energised) collectively connected to a pair of contacts of the reversing switch 32.

[0046] The second group 31 of electromagnetic switches, of the SPDT type, comprises N+1 (N=4) relays, 38,39,40,41,42 with the common pole connected to the sockets 27,26,25,24 respectively, of the first group and to the socket 23 of the second group and with the normally open contact collectively connected to the other pair of contacts of the switch 32.

[0047] Obviously only one relay at a time of each of the two groups must be energised into closing to avoid the short circuit of a part of the autotransformer and the switching closed of any one of the relays must take place only when it is certain that the other relays of the same group, therefore all of those in the same group, are open.

[0048] Later on we shall see how this problem is solved in an innovative manner.

[0049] Here, to conclude the description of figure 2, it should be observed that to ensure the supply continuity of the load and at the same time to avoid short-circuiting, it is necessary to foresee by-pass devices and circuits.

[0050] Advantageously, the number of these circuits is less than the number of relays of each group: for the first group these consist of a single by-pass circuit, consisting of a relay 43 with the common pole connected to an intermediate tap 22 of the first group of tap and the contact which is normally open connected to the output node of the first group of relays through a current-limiting resistor 44.

[0051] For the second group of relays are foreseen, on the other hand, with rounding off in defect to the nearest integral number, (N+1)/2 by-pass circuits (thus in the figures 2 circuits) with the common pole respectively connected to taps of the second group separated by one tap, in figure 2 the intermediate tap 26,24, and with the contact which is normally open connected to the output node of the second group of relays through a common current-limiting resistor 47.

[0052] The value of the limiting resistors is suitably chosen to limit both the circulating current to acceptable values when a by-pass circuit is closed together with a relay of the corresponding group, and the voltage drop on the resistor, when the only by-pass circuit is closed and crossed by the feed current of the primary winding of the transformer 29 (which in the example described is a function of the load current in the ratio 1/7).

[0053] Therefore, for example, if the maximum current foreseen in the primary 28 is 4A the resistor 47 can indicatively have a value of 20Ω and the resistor 44 a value of 10Ω.

[0054] In addition the by-pass relays 43,45,46, which collectively constitute a third group 73 of relays, a further relay 48, which is normally open, is foreseen to short circuit the primary winding 28 of the transformer when the inverter switch is activated.

[0055] The inverter switch is activated when the voltage applied to the primary 28 is zero, that is when the relays 37 and 42 are closed and consequently the primary is in short circuit. In this condition the primary 28 and the secondary 33 reverse their roles: the transformer is fed with current through the winding 33 which functions as a primary. Since the winding 28, which functions as a secondary, is in short circuit, the drop in voltage on the winding 33 is negligible (due only to resistance and dispersion reactance).

[0056] If, however, the winding 28 is open, as happens during the course of the switching of the relay 32 (unless a mechanically polarised relay is foreseen which closes before opening and which is intrinsically slow and not very reliable) the transformer 29 behaves like an idle transformer, fed with current, that is as a reactance which introduces, as a function of the feed current, a high and unacceptable drop in voltage, at most limited by the saturation of the magnetic core, which significantly reduces the voltage applied to the load.

It is, therefore, appropriate that during the course of the switching of the inversion relay 32 the short circuit of the winding 28 be ensured.

[0057] Having described the structure of the power module one can immediately understand its function, as it is commanded by the control section 2B which comprises a microprocessor 49 with relative memory, driving circuits of the different relays and communication port with the control unit 1 (Fig.1).

[0058] To start up the system the control unit 1 firstly asks for a predetermined voltage to be supplied in output.

[0059] The control section 2B, after having measured the actual mains voltage available, determines, upon the basis of stored information, which of the relays of the first and of the second group must be closed and the position which the switch 32 must be in to obtain the desired voltage in output. Therefore, it commands their closing with a possible switching of the relay 32.

[0060] All of these operations are carried out at no load, preferably but not necessarily in sequence.

[0061] Through the closing of a pair of relays, at the output of the power section a voltage is made available which is measured and compared to the desired one.

[0062] If the differential is less than a certain value (also programmable) it is indicated to the control unit 1 that it can proceed to the connection of the load with the closing of the switch 18. Otherwise it is necessary to modify the output value, in general with just the opening of a relay of the first group and the subsequent closing of another relay of the same group.

[0063] For this adjustment, even if it is carried out at no load, a rigorous ordering must be respected between the opening of the first switch and the closing of the second. In other words the control section 2B must verify, by means of circuits discussed later on, that the first switch is actually open before putting the second relay into closed state.

[0064] The same condition must be verified also in the case where it is necessary to open (even simultaneously) both a switch of the first group and of the second. The closing of the switches which replace the first in closed state must take place subsequently. This is necessary to avoid the short-circuiting of portions of the autotransformer's windings.

[0065] More complex is the procedure to be followed to modify the output voltage under load, that is when the switch 18 is closed, both to keep the output voltage constant as the mains voltage varies, as well as to obtain in output a voltage which can vary according to a predetermined time profile established by the control unit 1 (ignition ramp, heating voltage, voltage reduction ramp, maintenance voltage).

[0066] In this case, before opening a relay, either of the first or of the second group, it is necessary to close a by-pass circuit, to make sure that the by-pass circuit is closed and, only after having carried out this check, to open the relay. After having checked that the relay to be opened is actually open one can proceed to the closing of the relay which must replace in closed position the one just opened. Finally, the by-pass circuit can only be opened after having checked that the relay already moved closed is actually closed.

[0067] The same procedure must be repeated, in sequence and after the first, in the case that to regulate the voltage to the desired value it is necessary to switch a relay both of the first and of the second group.

[0068] The procedure to be followed for the activation of the reversing switch 32 is entirely analogous.

[0069] Firstly, it is necessary to move closed the two relays 42,37, if they were not already closed, respecting the procedure already seen and to check that they are closed.

[0070] In this condition the voltage set for the primary 28 is zero. It is necessary to then move closed the short circuit relay 48 and preferably, even if not necessarily, check the state thereof.

[0071] Indeed, since the short circuit relay switches to a zero voltage between the contacts, there is no risk of electric arcs which could damage the contacts and cause, by welding, the jamming of the relay.

[0072] With the short circuit relay closed it is then possible to actuate the inverter switch 32 and finally to reopen the short circuit relay.

[0073] Also this opening switching takes place with zero voltage between the contacts and the current is switched onto the parallel short circuit path formed by the relays 37,42, which are closed, therefore without the development of an electric arc.

[0074] In this condition, with the procedures already seen it is then possible to establish a non -zero voltage in the primary 28 with the opening of one or other of the switches 37,42 or of both, and the closing of corresponding switches of the first and/or second group, taking care to activate the necessary by-pass circuits.

[0075] It is therefore clear, keeping in mind that the switching time of an electromagnetic relay is in the order of 10 ms, that switching procedures where a load is present require a non-negligible time, no less than 40 ms and than 80 ms when the switching of two relays of the first and of the second group is necessary.

[0076] In the absence of a check on the state of the relay, this time, for safety and to take account of the inevitable dispersions of the switching times, must necessarily be increased, separating the different operations in time, increasing the intervention times of the by-pass circuits and consequently the amount of energy dissipated and the duration of the voltage transients, reducing the regulation speed.

[0077] It is, therefore, desirable to have control circuits which allow the execution time of the procedures to be reduced to the minimum and which rapidly provide information that the different switching operations commanded have actually taken place.

[0078] This is even more important since, whereas the contacts of the inverter switch and of the short circuit relay open and close without the development of electrical arcs, the contacts of the other relays switch under a load, which is inductive what's more, with a non-zero voltage between the open contacts and consequently with the development of electrical arcs which can cause the welding and the jamming of the contacts which no longer obey the electromagnetic command of the relay.

[0079] From this point of view, more than desirable, it is mandatory to foresee control systems which provide the direct information of the contact switching having taken place, not mediated by the behaviour of auxiliary contacts, the behaviour of which does not necessarily reflect that of the contacts which must be monitored.

[0080] In this manner it is possible to avoid that a relay failure has catastrophic effects, timely blocking the further development of the switching procedures upon the first detection of the failure, carrying out attempts at repeating the command and, after a suitable number of attempts, for example three, having checked that the defect is permanent, definitively blocking the operation and indicating the failure.

[0081] Figure 3 shows a preferred embodiment of the circuits for checking the open/closed state of the switch contacts.

[0082] Firstly, let us consider the second group 31 of electromagnetic switches, comprising switches 38,39,40,41,42, with the common pole connected to the autotransformer tap at which there is the nominal voltage of 285,225,165,105 and 45V respectively.

[0083] The contacts which are normally closed or inactive of the two switches 38,39 are connected to the inputs of a detector circuit 50 which provides in output a logic signal 1 asserted (for example a voltage of about 5V) when both of the switches are in rest position and a logic signal 0 when even only one of the switches 38,39 is switched with the common pole closing on the active pole.

[0084] The structure of the detector circuit is very simple and comprises a rectifying bridge 51 connected to the inactive poles, which are normally closed, of relays 38,39, through a resistor 52 of a suitable value. The bridge feeds, in voltage rectified and filtered by a capacitor 72, through a second resistor 53, the light emitting diode of an optoelectronic coupler 54 whose phototransistor, connected between a suitable voltage (+5V) and ground, with a suitable resistance 55 in series with the emitter, imposes at the output, connected to the node between emitter and resistor 55, a logic signal 1 when the detector circuit is fed (that is, the switches 38,39 are both switched to open the active pole and to close the inactive pole) and a logic signal 0 when even only one of the switches is switched to close onto the active pole and therefore the detector circuit is not powered.

[0085] The value of the resistor 53 and of the capacitor 72 is chosen so that the time constant RC of the circuit has a predetermined value, in the order of 5ms.

[0086] The value of the resistor 52, in relation to that of the resistor 53 is chosen according to the feed voltage (in our case 60 nominal volts being the effective value) so that the light emitting diode is energised with a suitable current, for example 10mA.

[0087] Identical to that described is the structure of the detector circuit 56, with two inputs respectively connected to the inactive pole of the switches 40,41. The detector 56 recognises the open state (level 1 as output) of both of the switches or the closed state (level 0 as output) of even only one of the switches.

[0088] Substantially identical is also the structure of the detector circuit 57, with the only difference in the (lower) value of the resistor 52 within the circuit, to take account of the fact that the circuit has inputs connected respectively to the inactive pole of the switch 42 and to the tap with a nominal voltage of 30V so as to be fed (when the switch 42 is open) with a voltage of 15V.

[0089] This circuit reveals the open or closed state of the only switch 42.

[0090] The outputs of the detector circuits 50,56,57 are connected to the inputs of a NAND gate 58 which outputs a logic signal 0 when all of the switches of the first group 31 are open and a logic signal 1 when one of the group switches is closed.

Since only one of the group switches can and must be closed at once (otherwise a short circuit forms) the information in output from the gate 58 and applied in input to the microprocessor 49 (Fig.2) is adequate to check the open/closed state of the switches and to verify if a switch (activated one at a time) has correctly responded to the closing and opening commands.

[0091] Incidentally, it is suitable to note that to achieve maximum safety, the commands to close the switches of the same group are obtained by decoding a binary code, so as to rule out any possibility of commanding more than one switch of the same group to close simultaneously, due to an error or to a failure developed upstream of the decoder.

[0092] The information received from the microprocessor is not just adequate but is also rapid.

[0093] Indeed, when a switch is closed, the feeding of the detector circuit, which corresponds to the input signal, switches as soon as the inactive contact opens and before the closing onto the active pole takes place. The time constant of the detector circuit replaces the flight and bounce time of the mobile armature and ensures that the closing signal is received when the switching is definitely taking place and is about to be completed, without significant delays. In the same way, when the switch is opened, the detector circuit is supplied with current as soon as the common pole closes on the inactive contact and the switching has definitely taken place.

[0094] Therefore, it is not at all necessary to take account of the response time of the relay and of the possible dispersions thereof.

[0095] Totally identical to the structure of the detector circuit 57 is the structure of the detector circuits 59,60 with inputs connected to the inactive poles of the relays 37,36 and 35,34 respectively and outputs connected to the inputs of a NAND gate 61.

[0096] The NAND gate 61, like the gate 58, has in output a logic signal 0 when all of the relays of the group 30 are de-energised, thus open, and a logic signal 1 when one of the relays responds correctly to an energise command, closing itself.

[0097] Totally similar to the previous ones is the structure of the detector circuits 62, 63 which respectively monitor the state of the by-pass relays 45,46 and the state of the by-pass relay 43.

[0098] In particular circuit 63 is identical to circuit 57 already described, receiving in input a voltage of 15V, and circuit 62, receiving in input a voltage of 120V, differs from circuit 50 only for the fact that it has a higher value of the internal resistance 52.

[0099] The outputs of circuits 62,63, arranged in logic NAND from gate 64, provide a logic signal 0 when all of the by-pass circuits are open and a logic signal 1 when one of the by-pass circuits is closed.

[0100] Although it is not indispensable, it is also possible to foresee a circuit 65 to detect the open or closed state of the short circuit switch 48.

[0101] The structure of the detector circuit 65, a diagram of which is shown in the figures, is similar to that of circuit 50 and differs from the latter only because the former foresees, as well as the inversion of the output signal (obtained with the grounding of the phototransistor emitter and the connection of the output to the collector), a Zener diode 66 in parallel with the capacitor 52. The Zener diode limits the current injected into the light emitting diode.

[0102] Indeed, in this case the voltage applied in input, according to the different working conditions of the regulation system, can vary from 0 to 165V (a voltage of 165V is applied to one input and a variable voltage from 0 to 285V is applied to the other).

[0103] It should immediately be noted that the response of circuit 65 is ambiguous: the outlet signal depends not just upon the open or closed state of switch 48 but also on the input voltage which can be 0 or so low (15÷45V) as not to lead to the energising of the optoelectronic device.

[0104] The ambiguity can be solved remembering that the short circuit relay can and must be moved closed only when switches 42 and 37 are both closed and the voltage of 45V referring to the neutral is applied to both of the poles of the inverter switch 32.

[0105] In this condition the circuit receives in input a voltage of 120V, which is more than adequate.

[0106] This condition can be taken account of directly by the microprocessor 49 (which knows when switches 42 and 37 are closed because it is the microprocessor itself which commands its closing) and in this case the output of circuit 64 can be connected to an input gate of the microprocessor.

[0107] Yet more advantageously, as represented in figure 3, it is possible to connect the output of circuit 65 to an input of NAND gate 64, with the intermediary of a NAND gate 67 with a masking function.

[0108] Two signals CL42 and CL37 (available in output from the microprocessor 49) which close the two switches 42 and 47 are applied to two inputs of NAND gate 67.

[0109] The state 1 present at the output of circuit 65 is transferred (with inversion) to the input of NAND 64, only if CL42 and CL37 are at 1. Otherwise NAND gate 67 applies the logic signal 1 in input to gate 64 and masks the ambiguous states of the detector circuit 65.

[0110] It must also be noted that the closing of the short circuit relay does not take place at the same time as the intervention of the by-pass relays, for which reason the information in output from the NAND gate 64 can be interpreted without any ambiguity and referring to the particular relay which is activated from time to time.

[0111] In conclusion, with the described detector circuits it is possible to recognise the switching of all of the switches of the power section, detecting it directly on the contacts, in a reliable and rapid manner, without delays to ensure a safety margin for dispersions in behaviour.

[0112] Only the behaviour of the reversing switch 32 cannot be monitored with detector circuits of the type described because at the intervention step all of the contacts have the same potential.

[0113] This does not constitute a problem because the lack of switching does not carry the risk of catastrophic failures and ends up with the impossibility of obtaining the desired variation of the output voltage.

[0114] It is therefore possible to detect the non-operation of the switch, straight afterwards, by simply verifying if the variation in voltage which comes about from an immediately subsequent procedure of switching the group relays is in the desired direction or else the opposite direction.

[0115] In the previous description the optimised management system was essentially considered as a voltage regulation system.

[0116] From this point of view the system described, thanks to the fineness of regulation which is allowed (furthermore capable of being incremented even only slightly increasing the number of taps of the autotransformer and the corresponding number of relays) and thanks to the speed of response, can be conveniently used as a voltage stabiliser for the feeding of whatever type of load, as well as a programmable voltage regulator for feeding whatever type of load, the voltage of which must be regulated and possibly modified for whatever reason (for example for "margining" operations in a laboratory or to regulate the speed of motors fed in alternating current, replacing TRIAC partialising devices which do not allow the mains voltage to be increased and in particular have the serious drawback of introducing high width harmonics in the developed waveform.

[0117] However, it is clear, as has been highlighted, that the described system can also operate as a brightness regulator, keeping in mind that the light emission is to a great extent dependent upon the feed voltage of the bulbs and the brightness of an environment also depends upon the possible variable light contribution coming from the outside. Therefore, a direct relationship between feed voltage and brightness of the room does not exist.

[0118] For this purpose it is sufficient to foresee a brightness sensor 11 (Fig.1) and to slave the operation of the system to the signal emitted by the sensor, conveniently converted into digital form and compared with a desired brightness value.

[0119] The brightness sensor can also carry out a twilight function and the system can be programmed, obviously with suitable hysterisis, to switch on a light bulb when the brightness falls below a certain level, to keep the lighting at a desired level, in case variable according to time bands, and to switch off the light bulb if the brightness goes above another predetermined level.

[0120] A specific application of this type consists of the regulation of lighting in tunnels.

[0121] It is known that current lighting units for tunnels can consist of a line which is always switched on, known as "permanent" lighting, of a second low consumption line which is always switched on even in the case of a power cut since it is fed from UPS (Uninterrupted Power Supply), known as tracing, and of a certain number of intensifying circuits (generally from 1 to 3, according to the length of the tunnel) which switch on or off in relation to the brightness outside, to reduce glaring effects when leaving the tunnel and to allow the gradual adaptation to the lighting inside upon entering.

[0122] This solution offers only four brightness values and cannot adapt to all the intermediate conditions.

[0123] The system which has been described, appropriately replicated to constitute a piece of equipment, also effectively solves this problem and allows the brightness to be regulated gradually, with a high resolution, by controlling the selective intervention of the intensifying circuits according to the brightness outside.

[0124] To better understand this aspect it is suitable to refer to figure 1.

[0125] In figure 1, as well as the base system which has been described, hereafter known as unit A, two other units B and C, identical to the previous one, are present.

[0126] For simple reasons of constructive modularity and of programming, units B and C are each equipped, like unit A, with a central unit, such as 1, with at least one power module, such as 2, and with a keyboard, such as 3, so as to be able to be programmed individually in a coordinated manner.

[0127] However, it is obvious that a single keyboard, with a bus connection, represented by the dashed line 104 can be used to program the operation of the three units.

[0128] The element common to the three units which completes the equipment consists of an auxiliary module 130 and of a brightness sensor 10 which, through the auxiliary module 130, sends a binary code, representing the level of brightness outside, to the three units on respective optoinsulated serial ports.

[0129] It should be noted that, in place of the bus 104 and of a keyboard dedicated to each unit A, B and C the auxiliary module 130 could allow the exchange of information between the different units A, B, C and the programming thereof with a single keyboard.

[0130] Unit A can be programmed to manage the permanent line, unit B to manage the intensifying line or lines and unit C to manage the tracing line, all according to the brightness outside, measured with a single sensor 10.

[0131] Figure 4 represents in a voltage V/external brightness level L qualitative diagram, a preferred form of regulation of the voltage for the different lighting lines.

[0132] For external brightness values less than L1 units A and C supply to the permanent line (P) and to the tracing line (T) a feed voltage which increases with the external brightness. The voltage can be different for the two lines but, for clearness of representation it is represented as equal.

[0133] When the external brightness is greater than L1 unit B activates the feed of a first intensifying line RNF1, whereas the feed of the permanent line and of the tracing remain unchanged, as represented in the figures. If so desired, for very long tunnels or for particular requirements the feed voltage of the permanent and tracing lines could also be reduced and subsequently incremented.

[0134] It is clear that initially the voltage necessary for switching on and heating is applied to the intensifying line, said voltage then being reduced to a suitable value.

[0135] As the brightness outside increases, the feed voltage of the intensifying line is increased from L1 and L2.

[0136] When the external brightness is greater than L2, with the same criterion, the second intensifying line RNF2 is activated and the feed voltage of the other intensifying line is reduced.

[0137] Finally, if the external brightness is greater than L3, the third intensifying line RNF3, if present, is activated with the same criteria.

[0138] The same criteria is followed, with a suitable hysterisis, to reduce and remove the feed to the intensifying lines, in the case of reduction of external brightness.

[0139] Basically, at the entrance and at the exit of the tunnel a lighting LTOT which can be varied gradually, without substantial discontinuities, with the level of brightness outside L, is obtained.

[0140] To achieve a precise regulation of brightness, according to one aspect of the present invention and unlike prior art systems which use photovoltaic cells and expensive equipment, the system object of the present invention uses a photoresistor, which is more cost-effective, more reliable and, being appropriately driven, allows greater precision of measurement and of regulation in all possible ranges of brightness.

[0141] Figure 5 schematically represents the brightness measuring apparatus adopted.

[0142] A photoresistor 10, remote from the regulation system, is connected to the auxiliary module 130 with a screened cable 78 which protects it to a large extent from disturbances and atmospheric discharges.

[0143] The photoresistor 10, in parallel with a resistor 70 and in series with a resistor 71 which functions as a voltage divider, is fed by a continuous regulated and constant voltage of -5V.

[0144] The node which is common to the photoresistor and to the resistor 71 is connected to the inverting input of an operational amplifier 74, with suitable feedback provided by a trimming resistor 75, to ensure a predetermined gain.

[0145] Two diodes 72,73 connected between the inverting input and voltages of +5V and -5V respectively, ensure the protection of the amplifier against overvoltages taken on through the input cable 78.

[0146] Not-shown capacitors, in a known way, filter the transient noise and cutting the frequency response of the amplifier.

[0147] The output of the amplifier 74 is connected to an analogic input port of an integrated circuit for the acquisition and A/D conversion of signals which circuit outputs, on three serial ports, and sends to units A,B,C a binary code representing the input signal, in turn representing the resistance of the photoresistor 10 and, fundamentally, the measured level of brightness outside.

[0148] Through serial input ports, not illustrated, the circuit can be programmed, to assign and characterise the ports with which it is equipped as analogue or digital input ports.

[0149] Other aspects of the integrated circuit are not essential.

[0150] The auxiliary module 130 is fed by an AC/DC power supply 79, connected to the output of the transformer 6 (Fig.1) and buffered by a battery 77 which ensures the powering of the module even when there is a main shut down. The power supply 79 supplies the necessary continuous feed voltages to the module.

[0151] In this way all of the functions necessary for acquiring the brightness value, which is indispensable for the control of the lighting of tunnels and more generally of units dependent upon conditions of brightness outside are gathered in an auxiliary module and do not burden the cost of the base system which in many cases must only operate as a programmable voltage stabiliser or regulator.

[0152] In relation to the use of the described system for the optimised management of a lighting unit of the gas discharge type it is interesting to note a special function, capable of being achieved with the system, consisting of testing the unit to identify bulbs which are defective and/or nearly run out.

[0153] It is known that when a gas discharge bulb has nearly reached the end of its useful life, it finds it difficult to keep its switched on state and is particularly sensitive to rapid reductions in the feed voltage up to a minimum necessary value, to remain switched on.

[0154] The described system, indeed, allows these rapid variations in voltage to be obtained through a command made manually from keyboard 3 (fig.1).

[0155] Indeed, it is possible to command a switching on and warming up sequence, and with this having been carried out a rapid reduction in the maintenance voltage can be commanded, in quick succession switching the relays of the second group (31, Fig. 2) so as to impose relatively wide variations in voltage, in the described example in the order of 8.4V without passing through the selective activation of the relays of the first group.

[0156] This operation can be carried out in a very brief space of time, in the order of 100 ms, and it can be followed, in an equivalent time, by the restoration of the normal switching on conditions.

[0157] As a result of this rapid voltage variation, which substantially consists of a margining operation during the course of the exercise, the bulbs which are defective and/or nearly run out remain switched off.

[0158] This allows the programmed replacement, following the testing operation or even at an appropriate subsequent time, of all of the bulbs which are defective and/or have nearly run out.

[0159] In this way the number of necessary maintenance operations is reduced, to the great advantage of the operative state of the equipment in the cases in which it is intended to operate in continuous duty.

[0160] The previous description refers to a preferred embodiment of a system for the optimised management of lighting units and it is clear that many variants, in addition to those already indicated, can be made.

[0161] For example, the different switching relays can all be individually equipped with a switch detecting circuit, as is the case for relays 57 and 63 of figure 3, with outputs of the detector circuits arranged by groups in logic NAND or else connected directly to corresponding ports of the microprocessor, or even connected to a reduced number of ports and at the extreme to only one, through a multiplexer.

Claims

1. Programmable voltage stabiliser and regulator system, in particular for the optimised management of a load (Z), consisting of bulbs of the gas discharge type, comprising a control unit (1), sensors of the mains voltage (15) and of the regulated output voltage (16), and a power module (2A,2B) with autotransformer with a plurality of taps (20,21,...27), selectively connected to the inputs of the primary winding (28) of an auxiliary transformer (29), having the secondary (33) in series with the load (Z), through a plurality of electromagnetic relays and with the interposition of an inverter switch (32), **characterised in that**:

   said autotransformer is equipped with a first group of M ordered taps (20,21,22,23), where M>2, spaced apart by K turns, and with a second group of N ordered taps (24,25,26,27), where N>2, spaced apart by K • M turns, the tap (23) of the first group and that (24) of the second group which are electrically closest to each other being spaced apart by K • M turns,

   and **in that** said plurality of electromagnetic relays comprises a first group (30) of M relays, with a common output node, for the selective connection, one at a time, of the taps of said first group to a terminal of said primary winding (28) of said auxiliary transformer, and a second group (31) of N+1 relays, with a common output node, for the selective connection to the other terminal of said primary (28), one at a time, of the taps of said second group and of the tap of the first group which is electrically closest to those of the second group.

2. System according to claim 1 wherein M=4 and N=4.

3. System according to claim 1 or 2 comprising only one first resistive by-pass route (43,44) of said first group of relays (30), controlled by a first electromagnetic by-pass relay (43), to connect an intermediate tap of the first group of taps to the common output node of the relays of said first group (30), and at least one second resistive by-pass route (45,46,47) of said second group of relays (31), controlled by a second electromagnetic by-pass relay (45,46), to connect at least one intermediate tap of the second group to the common output node of the relays of said second group of relays (31).

4. System according to claim 3 comprising:

- a first group of circuit means (59,60) connected to the normally open inactive pole of each of the relays of said first group (30) to detect the open/closed state of said relays and to produce in output corresponding signals,
- a second group of circuit means (50,56,57) connected to the normally open inactive pole of each of the relays of said second group (31) to detect the open/closed state of said relays and to produce in output a corresponding signal, and
- a third group of circuit means (62,63) connected to the normally open inactive pole of each of the by-pass relays of said third group (73) to detect the open/closed state of said by-pass relays and to produce in output a corresponding signal.

5. System according to claim 4 wherein said circuit means comprises an optoelectronic device for electrically insulating the output from the input connections.

6. System according to claim 4 or 5 comprising a first (58), second (61) and third (64) logic gate which receive in input the output signals of said first, second and third group of circuit means, respectively, and produce in output, for each group of relays respectively, a signal representing the open state of all of the relays of the group, or the closed state of at least one of the relays of the group.

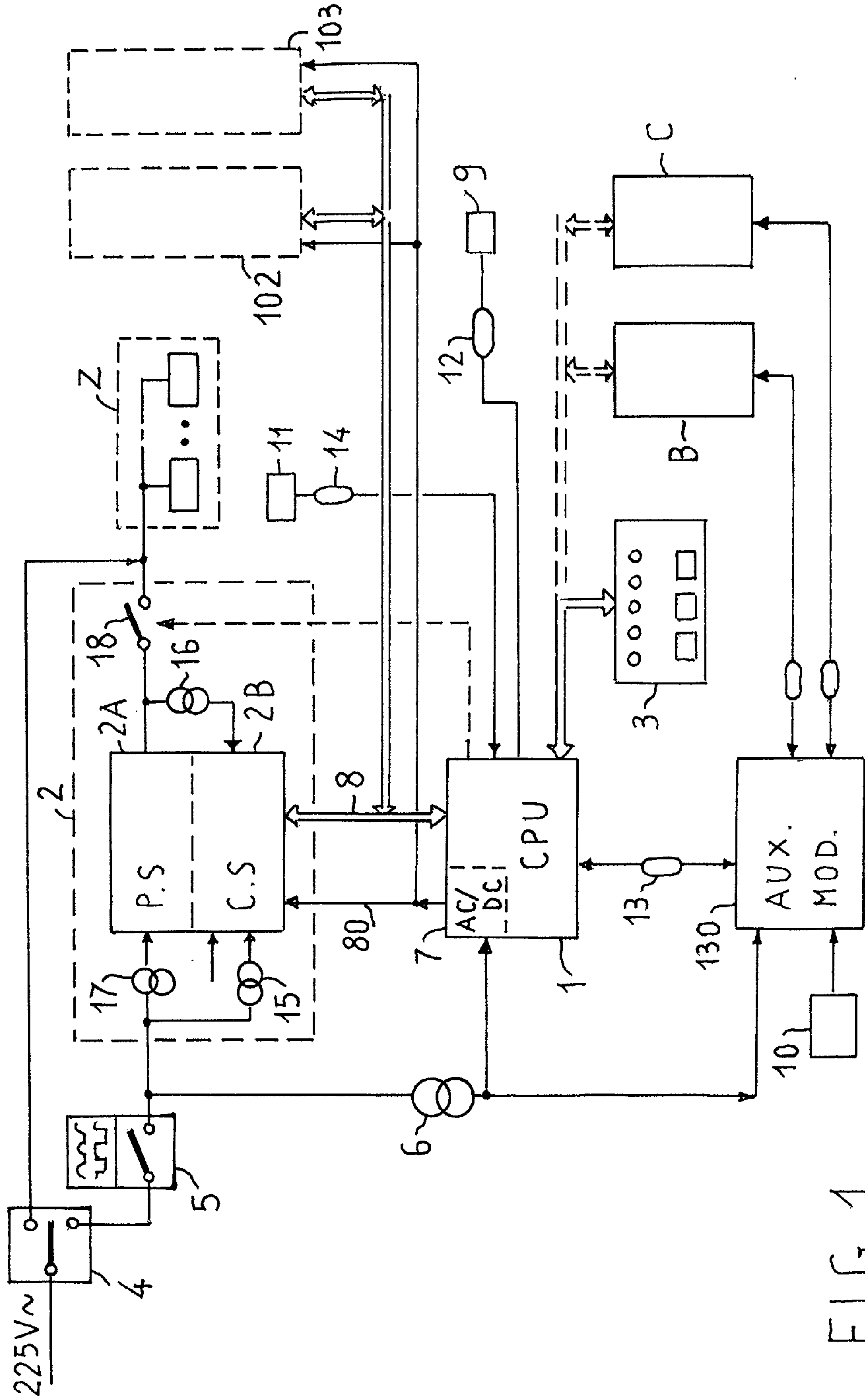
7. System according to claim 4,5 or 6 comprising a short circuit relay (48) of said primary (28) of the auxiliary transformer, and circuit means (65) connected to the normally open inactive pole of said short circuit relay to detect the open/closed state of said relay and to produce in output a corresponding signal.

8. System according to claim 4,5,6 or 7 comprising logic control means (49) receiving in input said signals representing the open/closed state of said relays of the first, second and third group, to subordinate, for each group, the closing of one of the relays to the prior detection of the open state of all of the relays of the group, to subordinate the opening of one of the relays of the first or second group to the prior detection of the effective closing of a corresponding by-pass relay, and to subordinate the opening of said corresponding by-pass relay to the detection of the effective closing of a relay of the first or second group.

9. System according to any one of the previous claims comprising a photoresistor (10) and an auxiliary module to convert the variations in resistance of said photoresistor into a binary code sent to said control unit (1).

10. Equipment for the regulation of the lighting in tunnels comprising at least one system according to any one of claims from 1 to 8 and a system according to claim 9.

11. Method for testing a bulb unit managed by a system or equipment according to any one of the previous claims, consisting of performing a rapid reduction in the feed voltage with the selective closing of only the relays of said second group (31).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2
2A
2B
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C.S
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17
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Z
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80
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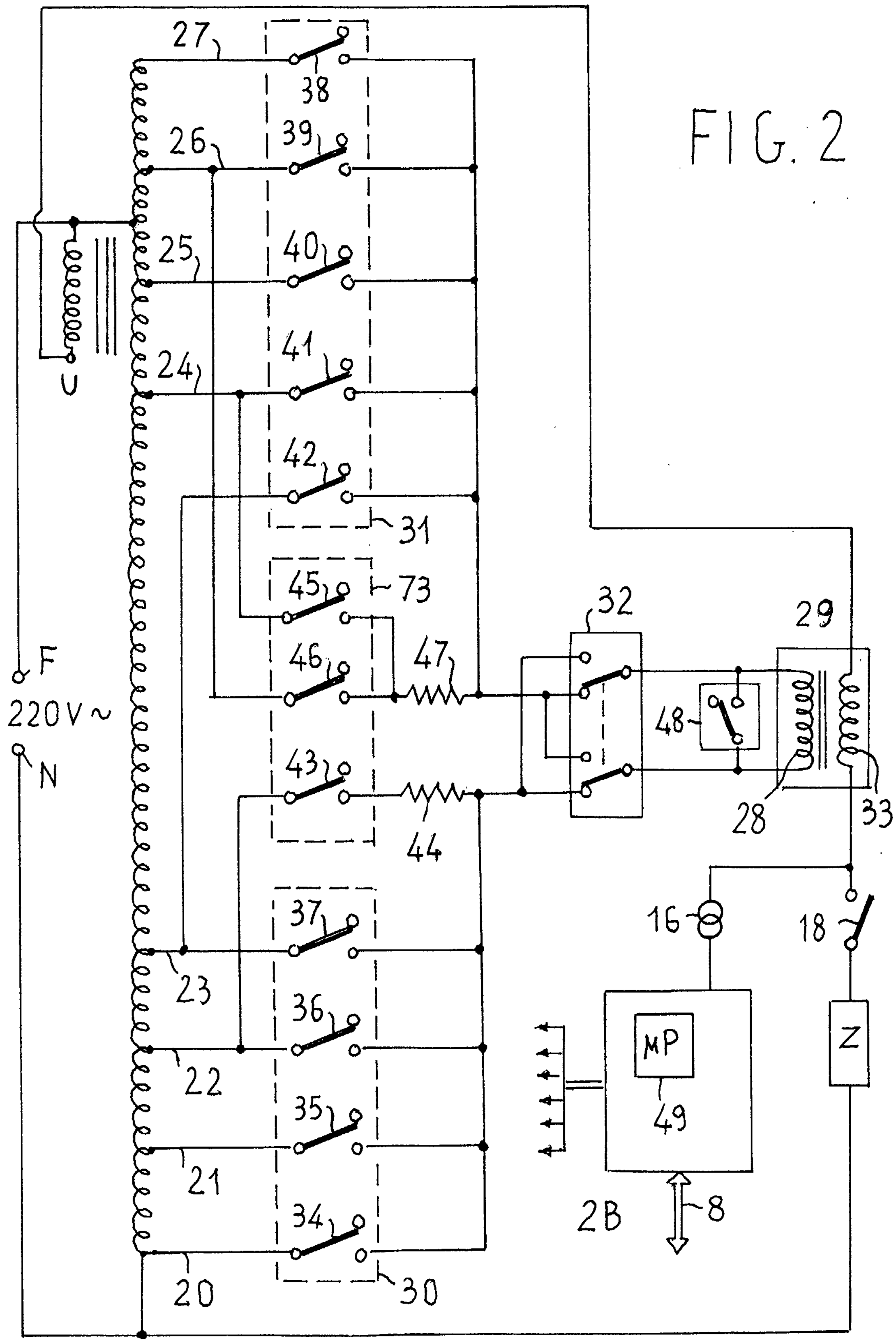
AC/
DC
CPU
1
11
14
12
9
3
B
C
13
130
AUX.
MOD.
10

FIG. 1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43
28
33
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22
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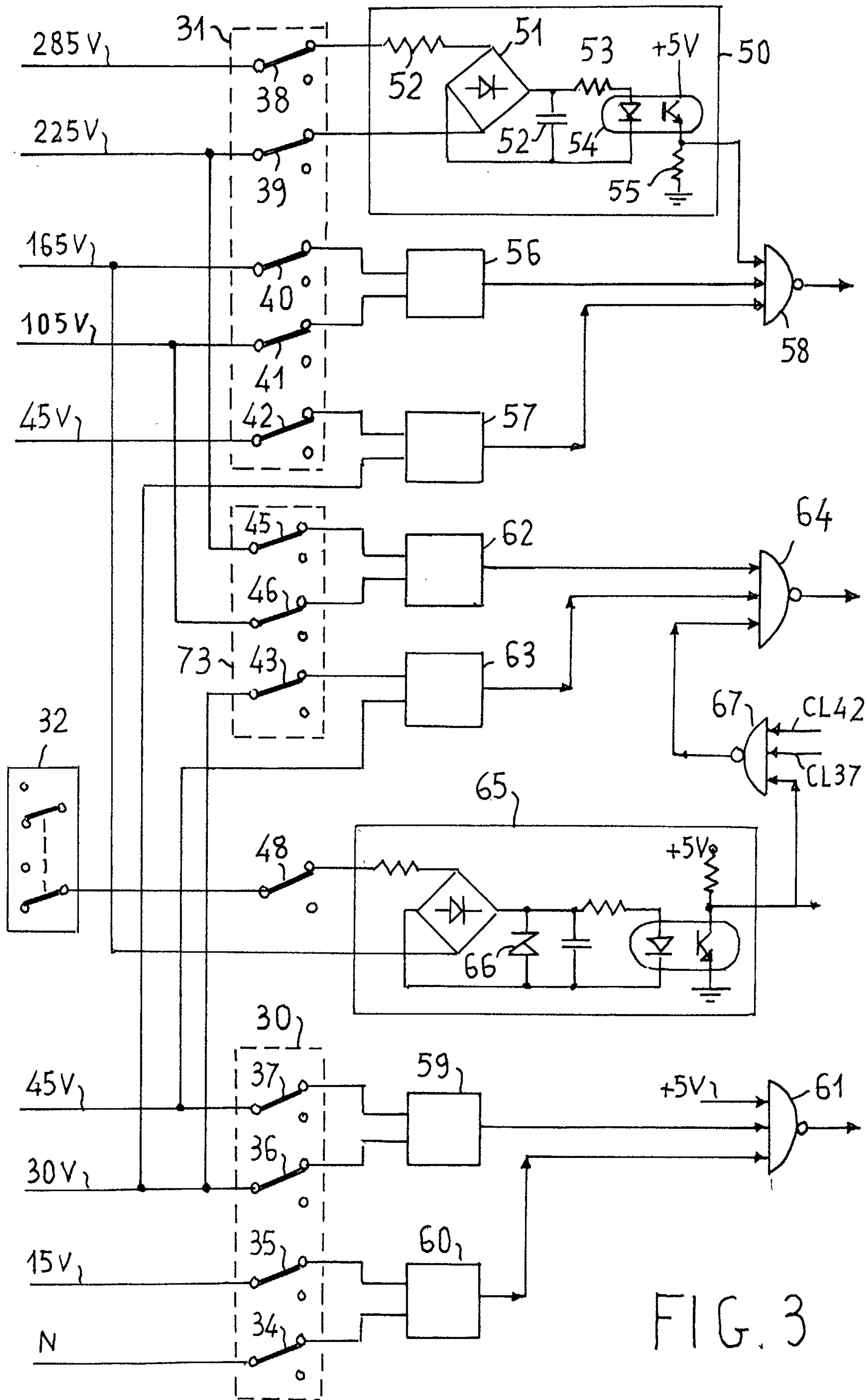
49
21
34
2B
8
20
30

FIG. 2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225V
165V
105V
45V
31
38
39
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50
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52
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56
57
58
45
46
73
43
62
63
64
67
CL42
CL37
32
65
48
+5V
66
30
37
36
35
34
45V
30V
15V
N
59
60
61
+5V

FIG. 3

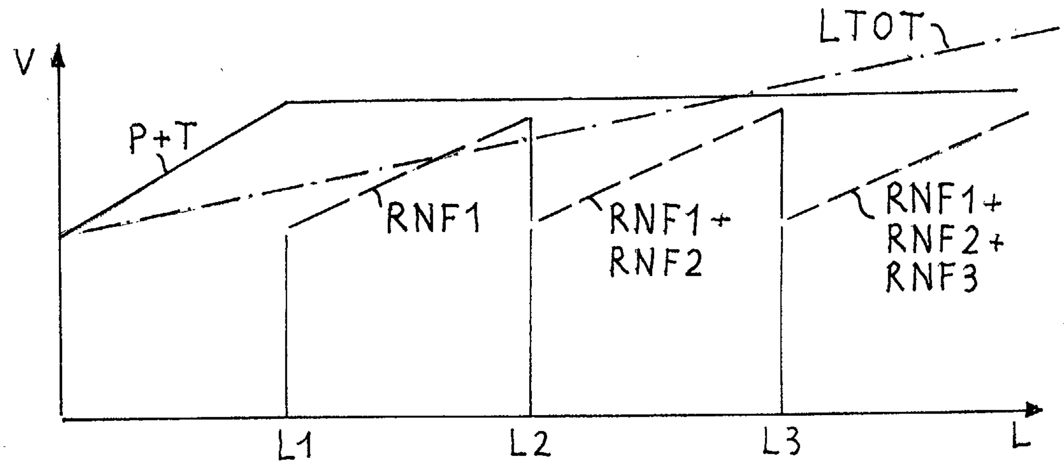
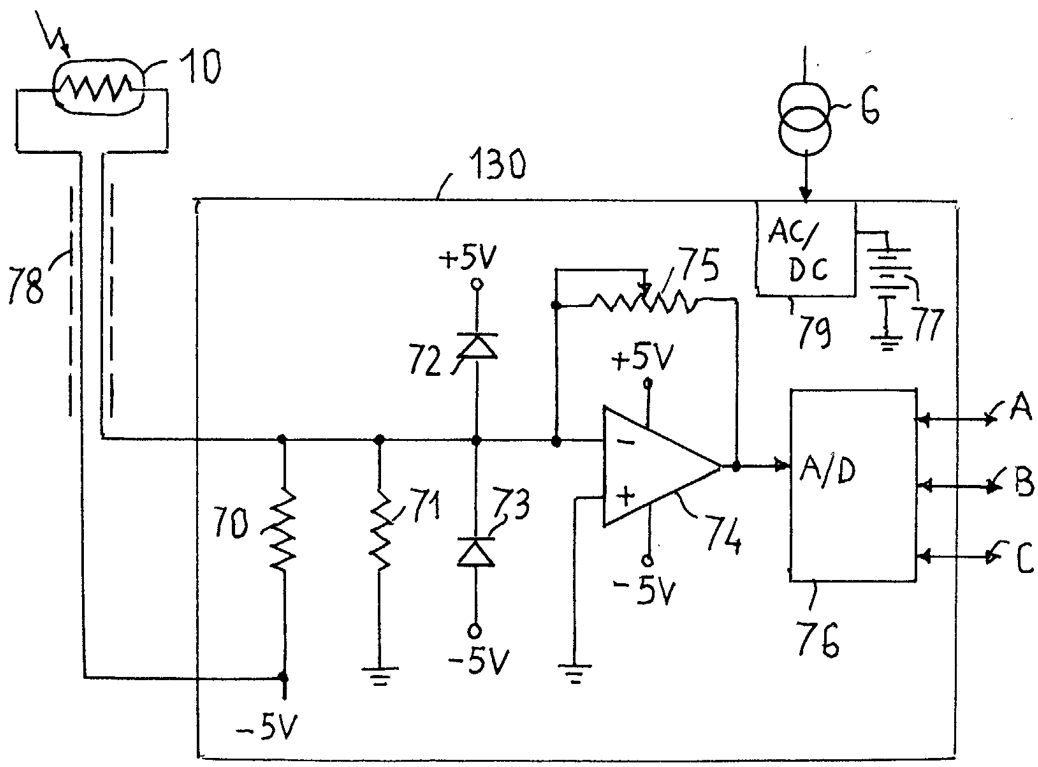

V
LTOT
P+T
RNF1
RNF1+
RNF2
RNF1+
RNF2+
RNF3
L1
L2
L3
L

FIG. 4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6
130
78
AC/
DC
+5V
75
79
77
72
+5V
A
A/D
B
70
71
73
74
C
-5V
76
-5V
-5V

FIG. 5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23 May 2002	Albertsson, E

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			DK	687135	T3	07-10-1998
			EP	0687135	A2	13-12-1995
			ES	2116650	T3	16-07-1998
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