United States Patent

Vukasovic et al.

[15] **3,643,405**

[45] **Feb. 22, 1972**

[54] CIRCUIT ARRANGEMENT FOR AUTOMATIC CONTROL OF THE VOLTAGE OF AN ELECTRICAL FILTER

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[22] Filed: **Mar. 6, 1970**

[21] Appl. No.: **17,176**

[30] **Foreign Application Priority Data**

Mar. 8, 1969 Germany ..... P 19 11 924.5
Mar. 8, 1969 Germany ..... P 19 11 925.6

[52] **U.S. Cl.** **55/105,** 55/139, 323/23
[51] **Int. Cl.** **B03c 3/66**
[58] **Field of Search** ..... 55/105, 2, 159, 104, 106, 107; 323/23 SC

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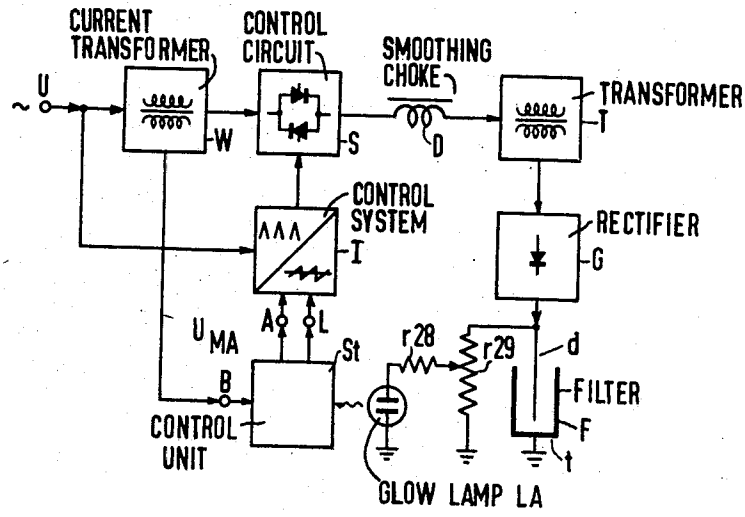
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[57] **ABSTRACT**

A control unit comprises a charging circuit which connects a guide capacitor to a source of DC voltage whereby a control voltage supplied to a control system is produced by the control unit in accordance with the voltage of a guide capacitor. A discharging circuit is connected in parallel with the guide capacitor and includes a controllable resistor having a resistance value dependent upon the voltage of the filter. A photoelement is in operative proximity with a glow lamp in a manner whereby light produced by the glow lamp impinges on the photoelement. The photoelement is coupled by a circuit to the discharging circuit for supplying a control signal dependent upon the irradiation of the photoelement whereby the control signal controls the controllable resistor of the discharging circuit to a low resistance value when the glow lamp does not glow and controls the controllable resistor to a high resistance value when the glow lamp glows. A cutoff circuit supplies a cutoff signal to the control system and the control system controls a control circuit to interrupt the filter current without delay when a sparkover occurs in the filter.

11 Claims, 2 Drawing Figures



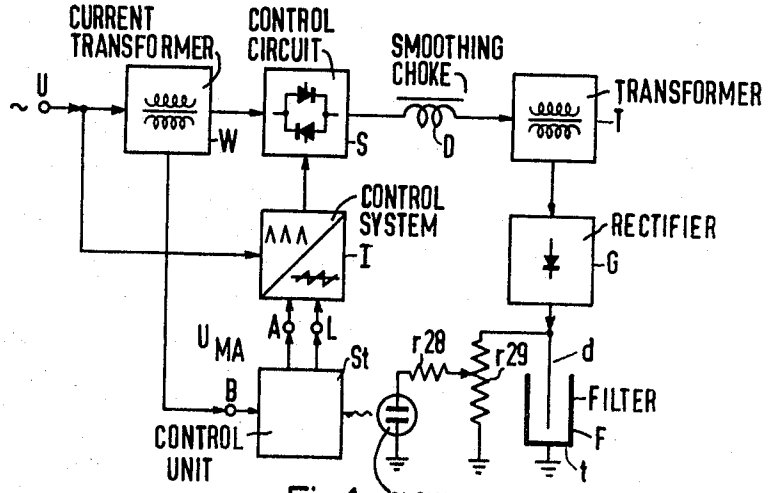

CURRENT TRANSFORMER
CONTROL CIRCUIT
SMOOTHING CHOKE
TRANSFORMER
U
W
S
D
T
CONTROL SYSTEM
I
RECTIFIER
G
A
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U MA
St
r28
r29
d
B
FILTER
F
CONTROL UNIT
t
GLOW LAMP LA

Fig.1

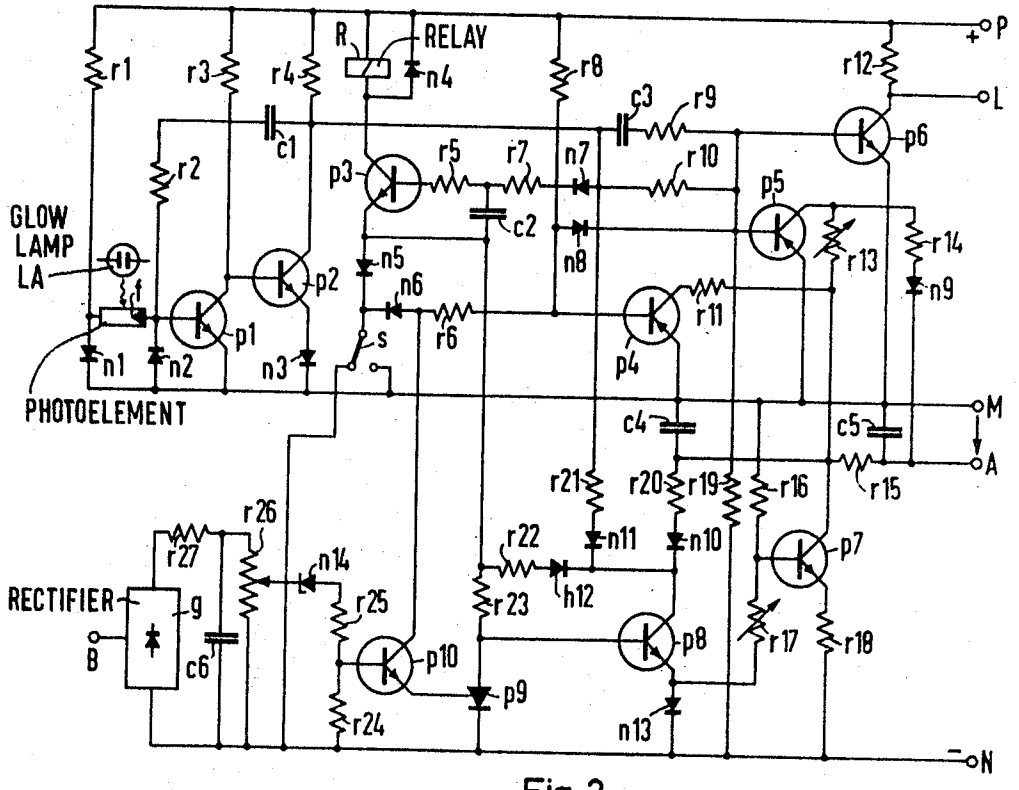

R
RELAY
n4
r1
r3
r4
r8
r12
P
L
c1
c3
r9
p6
r2
p3
r5
r7
n7
r10
p5
GLOW LAMP LA
c2
n8
r13
r14
n5
p2
n6
n9
p1
r6
r11
s
p4
n1
n2
n3
PHOTOELEMENT
M
c4
c5
A
r21
r20
r19
r16
r15
r26
r27
n14
r22
n11
n10
p7
RECTIFIER
g
r25
r23
h12
r17
r18
B
c6
p10
p8
p9
r24
n13
N

Fig. 2

CIRCUIT ARRANGEMENT FOR AUTOMATIC CONTROL OF THE VOLTAGE OF AN ELECTRICAL FILTER

DESCRIPTION OF THE INVENTION

The invention relates to the control of the voltage of an electrical filter, such as an electrical precipitator. More particularly, the invention relates to a circuit arrangement for the automatic control of the voltage of an electrical filter.

A control circuit controls the filter voltage. A control system supplies a control magnitude to the control circuit, which magnitude varies in accordance with a control voltage supplied to a control unit, which control unit is in turn connected to the control system. The control unit includes a guide capacitor connected to a source of DC voltage via a charging circuit. The control voltage depends upon the voltage of the guide capacitor. A discharge circuit is connected in parallel with the guide capacitor and contains a controllable resistor having a resistance value which depends upon the filter voltage.

The control circuit may comprise a control transformer, a transducer, a positioner including thyristors, or a controlled rectifier. The source of energizing voltage may be single or multiphase.

Known circuit arrangements of the aforedescribed type have essentially not been utilized, since the galvanic connection between the filter, conducting high voltage, and the control circuit, resulted in difficulties. These difficulties may be avoided by our invention.

Tests have shown that after a sparkover in the filter, a considerably higher current flows temporarily through the filter. This results in higher maintenance costs and causes the filter to have a shorter lifespan. The temporarily increased filter current is due to the control circuit and control system having time constants, which time constants prevent the filter voltage from being decreased without delay after the occurrence of a sparkover in the filter.

The principal object of the invention is to provide a new and improved circuit arrangement for the automatic control of the voltage of an electrical filter.

An object of the invention is to provide a circuit arrangement for the automatic control of the voltage of an electrical filter which overcomes the difficulties ensuing in similar circuit arrangements previously known.

An object of the invention is to provide a circuit arrangement for the automatic control of the voltage of an electrical filter, which circuit arrangement has lower maintenance costs and results in a longer lifespan for the filter.

An object of the invention is to provide a circuit arrangement for the automatic control of the voltage of an electrical filter, which circuit arrangement prevents the temporary occurrence of an increased current magnitude after sparkover in the filter.

An object of the invention is to provide a circuit arrangement for the automatic control of the voltage of an electrical filter, which circuit arrangement interrupts the filter current by a control circuit whenever a sparkover occurs in the filter.

An object of the invention is to provide a circuit arrangement for the automatic control of the voltage of an electrical filter, which circuit arrangement includes a control system for controlling a control circuit having thyristors by cutting off the supply of control pulses to the thyristors when a sparkover occurs in the filter.

The termination of the cutoff of control pulses, or the reinstallment of said control pulses would result in an abrupt increase in the filter voltage and thereby cause an overshooting of said filter voltage. Another object of the invention is therefore to provide a circuit arrangement for the automatic control of the voltage of an electrical filter, which circuit arrangement prevents overshooting of the filter voltage.

An object of the invention is to provide a circuit arrangement for the automatic control of the voltage of an electrical filter with efficiency, effectiveness and reliability.

In accordance with the present invention, a circuit arrangement for automatic control of the voltage of an electrical filter comprises a control circuit coupled to an electrical filter for changing the voltage of the filter. A source of voltage is coupled to the control circuit. A control system has an input coupled to the source of voltage, input means and an output connected to the control circuit for supplying to the control circuit a control magnitude. The control magnitude depends upon a control voltage supplied to the input means of the control system. A voltage divider connects a glow lamp in parallel with the filter. A control unit has an input coupled to the source of voltage and output means coupled to the input means of the control system. The control unit comprises a source of DC voltage. A charging circuit connects a guide capacitor to the source of DC voltage whereby the control voltage supplied to the control system is produced by the control unit in accordance with the voltage of the guide capacitor. A discharging circuit is connected in parallel with the guide capacitor and includes a controllable resistor having a resistance value dependent upon the voltage of the filter. A photoelement has a photosensitive area provided in operative proximity with the glow lamp in a manner whereby light produced by the glow lamp impinges upon the photosensitive area of the photoelement. Circuit means couples the photoelement to the discharging circuit for supplying a control signal dependent upon the irradiation of the photosensitive area of the photoelement whereby the control signal controls the controllable resistor of the discharging circuit to a low resistance value when the glow lamp fails to glow and controls the controllable resistor to a high resistance value when the glow lamp glows.

The control unit further comprises a reversing switch. A switching component has a switching condition which depends upon the switching position of the reversing switch and the magnitude of current flowing through the filter. The switching component is in its conductive condition only during the time between the energization of the circuit arrangement, with the assistance of the reversing switch, and the time during which the current flowing through the filter reaches a critical value for the first time after the energization of the circuit arrangement by the reversing switch. The switching component is connected in a manner whereby the control signal is ineffective when the switching component is in its nonconductive condition.

The control unit further comprises auxiliary circuit means connecting the switching component in parallel to the charging circuit of the guide capacitor.

The control unit further comprises a capacitor. A monostable multivibrator has a pair of input and output transistors of the same conductivity type and the controllable resistor of the control unit comprises a first transistor having a base-emitter path coupled via the capacitor and a resistor to the output of the monostable multivibrator whereby when the glow lamp glows, the input transistor of the monostable multivibrator is in its fully conductive condition. The output of the monostable multivibrator is connected to the negative polarity terminal of the source of DC voltage via a resistor, a decoupling diode and the emitter-collector path of a second transistor. The switching component comprises the second transistor whereby when the second transistor is in its fully conductive condition approximately the same potential is applied at the output of the monostable multivibrator as at the extinguished glow lamp, a third transistor having a control path connected in parallel with the first transistor and a base electrode. A diode connects the base electrode of the third transistor to a reversible voltage divider and conducts the control current of the third transistor. The control current of the third transistor flows through the reversible voltage divider as long as the current flowing through the filter is below the critical value and the first transistor is in a condition other than its fully conductive condition.

The control unit further comprises a fourth transistor of the same conductivity type as the pair of transistors of the

monostable multivibrator. A relay has an energizing winding connected to the collector electrode of the fourth transistor. A control circuit for the relay winding includes the base-emitter path of the fourth transistor. The base-emitter path is connected to the relay winding. A decoupling diode connects the control circuit of the relay in parallel with the output of the monostable multivibrator in a manner whereby when the glow lamp glows and the second transistor is in its nonconductive condition a control current flows. The fourth transistor has an emitter electrode connected to the collector electrode of the second transistor. The emitter electrode of the fourth transistor has a potential of a magnitude which is such that when the second transistor is in its conductive condition the fourth transistor remains in its fully conductive condition.

In accordance with the invention, a circuit arrangement for automatic control of the voltage of an electrical filter comprises a control circuit coupled to an electrical filter for changing the voltage of the filter. A source of voltage is coupled to the control circuit. A control system has an input coupled to the source of voltage, input means and an output connected to the control circuit for supplying to the control circuit a control magnitude depending upon a control voltage supplied to the input means of the control system. A control unit has an input coupled to the source of voltage and output means coupled to the input means of the control system. The control unit comprises a source of DC voltage. A charging circuit connects a guide capacitor to the source of DC voltage whereby the control voltage supplied to the control system is produced by the control unit in accordance with the voltage of the guide capacitor. A discharging circuit is connected in parallel with the guide capacitor and includes a controllable resistor having a resistance value dependent upon the voltage of the filter. Cutoff circuit means supplies a cutoff signal to the input means of the control system. The control system controls the control circuit for interrupting the filter current without delay when a sparkover occurs in the filter.

The control circuit comprises thyristor means and the control magnitude supplied by the control system controls the thyristor means. The cutoff circuit means of the control unit switches the thyristor means of the control circuit via the control system when a sparkover occurs in the filter.

The cutoff circuit means of the control unit comprises a first transistor having an emitter-collector path and a control path. The cutoff signal is derived from a point in the emitter-collector path of the first transistor. A second transistor of complementary type to the first transistor has a control path connected in parallel with the control path of the first transistor. The controllable resistor of the discharging circuit comprises the control path of the second transistor. Each of the first and second transistors has a base electrode connected to a first voltage divider. The first transistor is in its fully conductive condition during normal operation of the filter. A third transistor of the same conductivity type as the first transistor is in its nonconductive condition during normal operation of the filter and switches to its conductive condition upon the occurrence of a sparkover in the filter. The third transistor has an emitter electrode coupled to the emitter electrode of the second transistor. The third transistor has a collector electrode coupled to the base electrode of the second transistor via a capacitor and a resistor. The collector electrode of the third transistor is connected to the tap point of the first voltage divider. The capacitor discharges via the control path of the second transistor when the third transistor is in its conductive condition whereby the discharging of the capacitor switches the second capacitor to its conductive condition. A second voltage divider is connected to the base electrode of the second transistor via a diode. The diode is connected with a polarity which is such that the second voltage divider is supplied a fully advanced control current via a reversing switch in an operating position of the reversing switch and said second transistor is in its nonconductive condition.

The control unit further comprises a fourth transistor functioning with the third transistor as a monostable multivibrator. The capacitor and the discharging circuit have time constants which prevent the termination of the fully conductive condition of the second transistor prior to the termination of the reset condition of the monostable multivibrator.

The control unit further comprises a diode connecting the second voltage divider to the reversing switch. A fifth transistor has an emitter-collector path connected to the second voltage divider via the diode. The reversing switch has an operable switching position wherein it connects the second voltage divider to the source of DC voltage and wherein the circuit arrangement further comprises a current transformer connected between the source of voltage and the control circuit and has an output connected to the input of the control unit for supplying a signal to the control unit when the current flowing through the filter exceeds a predetermined critical value. The fifth transistor of the control unit is fully controlled by the signal supplied by the current transformer to the control unit.

The control unit further comprises a resistor. A second guide capacitor is connected to the first-mentioned guide capacitor via the resistor. The control voltage is derived from the second guide capacitor. The controllable resistor of the discharging circuit is connected in parallel with the second guide capacitor via another resistor. The period of interruption of the filter current and the time constant of the second guide capacitor and the discharging circuit are adjusted to each other in a manner whereby upon the termination of the interruption the second guide capacitor is substantially completely discharged. The second guide capacitor and the resistor have a time constant which is such that the voltage of the filter increases a s rapidly as possible without overshooting.

It is frequently preferred that a signal be produced when the glow lamp remains extinguished for longer than a specific period of time, since this usually indicates a metallic short circuit in the filter. The relay is utilized for this purpose. The relay is coupled to the source of DC voltage via the emitter-collector path of a transistor, the control path of which receives the control signal. The relay is thus unable to produce a faulty alarm signal when the switching component is in its fully conductive condition, that is, during the acceleration period. The emitter electrode of the transistor may also be coupled to the switching component via a resistor and a diode, so that when the resistor has a suitable resistance value, the transistor will remain in its fully conductive condition even when the switching component is in its nonconductive condition.

In order that the invention may be readily carried into effect, it will now be described with reference to the accompanying drawing, wherein:

FIG. 1 is a block diagram of an embodiment of the circuit arrangement of the invention; and

FIG. 2 is a circuit diagram of the control unit S*t* of FIG. 1.

In FIG. 1, an electrical filter F is coupled to the secondary winding of a high voltage transformer T via a rectifier G. The electrical filter, also called electrical precipitator, is shown diagrammatically as a high voltage wire *d* and a grounded metallic tube *t*. The primary winding of the transformer T is coupled to an input terminal U of a single or multiphase AC voltage power system via a smoothing choke D, a control circuit S and a current transformer W. The current transformer W, the control circuit S and the smoothing choke D are connected in series circuit arrangement between the input terminal U and the transformer T. The smoothing choke D functions to improve the shape of the signals supplied to the transformer T. The control circuit S comprises thyristors connected in antiparallel arrangement, that is, with the anode of one connected to the cathode of the other and the cathode of the first connected to the anode of the second.

Control pulses for the thyristors of the control circuit S are supplied by a control system I. In order to synchronize the control system I, the alternating voltage of the AC voltage power supply, applied via the input terminal U, is applied to

said control system. A control voltage U_{MA} is applied to the control system I via an input terminal A. The control voltage U_{MA} determines the phase position of the control pulses relative to the alternating voltage of the AC voltage power supply. Control system I can consist of a known standard unit, for instance control unit *teb–p4 se* 401, manufactured by Siemens AG, Germany.

The provision of control pulses by the control system I may be blocked without delay, and without regard to the magnitude of the control voltage U_{MA}, by a cutoff signal supplied to said control system via an input terminal L thereof. The control voltage U_{MA} and the cutoff signal are supplied by a control unit S*t*. The cutoff signal is supplied to the control system I by the control unit S*t* when a short circuit or similar fault occurs in the filter F.

At the onset of operations, a specific instance may occur. The control voltage U_{MA} is applied to the control system I by the control unit S*t* and depends upon a signal supplied to said control unit by the current transformer W. The signal supplied by the current transformer W to the control unit S*t* is proportional to the filter current and indicates a short circuit, breakdown, light arc, or the like, in the filter F. The signal is obtained via a photosensitive semiconductor device included in the control unit S*t* and exposed to light produced by a glow lamp LA. The glow lamp LA is connected in parallel with the filter F via a pair of resistors *r*28 and *r*29, so that said glow lamp glows only when said filter is in operation. When a sparkover occurs in the filter F, the glow lamp LA is extinguished.

FIG. 2 illustrates the circuit arrangement of the control unit S*t*. The control unit S*t* includes a rectifier *g*, which is preferably a full-wave rectifier, and has applied to it via an input terminal B a voltage proportional to the filter current. The rectifier *g* is connected via a resistor *r*27 to an RC member *c*6, *r*26. The resistor *r*26 of the RC member has a variable resistance. The variable resistance of the resistor *r*26 is coupled in parallel with voltage divider *r*24, *r*25 via a Zener diode *n*14. The resistor *r*24 of the voltage divider *r*24, *r*25 is connected in parallel with a series circuit arrangement of the control path of a transistor *p*10 and a thyristor *p*9. The collector electrode of the transistor *p*10 is coupled to a positive polarity terminal P of a DC voltage source via a resistor *r*6 and a resistor *r*8. The emitter electrode of the transistor *p*10 is connected to the control electrode of the thyristor *p*9. The base electrode of the transistor *p*10 is connected to a common point in the connection between the resistors *r*24 and *r*25 of the voltage divider *r*24, *4*25.

The direct voltage source has, in addition to the positive polarity terminal P, a negative polarity terminal N and an intermediate terminal or tap M, and delivers a voltage of 24 volts between said positive polarity terminal and said intermediate terminal and between said intermediate terminal and said negative polarity terminal. A series circuit arrangement of a first guide capacitor *c*4, a resistor *r*20, a diode *n*10, the emitter-collector path of a a transistor *p*8 and a diode *n*13 is connected between the intermediate terminal M and the negative polarity terminal N. The base electrode of the transistor *p*8 is connected to the anode of the thyristor *p*9. The cathode of the thyristor *p*9 is connected to the negative polarity terminal N.

The emitter-collector path of a transistor *p*7 is connected in parallel with a resistor *r*20, a diode *n*10, the transistor *p*8 and the diode *n*13, all of which components are connected in series circuit arrangement. The emitter-collector path of the transistor *p*7 is connected in series circuit arrangement with a resistor *r*18. The base electrode of the transistor *p*7 is connected to a voltage divider *r*16, *r*17 which is connected between the intermediate terminal M and the emitter electrode of the transistor *p*8. The transistor *p*7 maintains constant a charging current flowing therethrough. The transistor *p*7 maintains the charging current constant at a value which may be readily adjusted, within a large range, by the variable resistor *r*17 of the voltage divider *r*16, *r*17, or by the resistor *r*18.

The first guide capacitor *c*4 is connected in parallel with a second guide capacitor *c*5 via a resistor *r*15. The control voltage U_{MA} is derived from the second guide capacitor *c*5 for the control system I. The capacitance of the second guide capacitor *c*5, however, is only a fraction of the capacitance of the first guide capacitor *c*4.

In order to discharge the first guide capacitor *c*4, in accordance with the filter current, said capacitor is connected in parallel with the emitter-collector path of a transistor *p*4 via a resistor 11. The base electrode of the transistor *p*4 is connected to the positive polarity terminal P via a resistor *r*8.

To discharge the guide capacitors during a sparkover in the filter F, the emitter-collector path of a transistor *p*5 is connected in parallel with the first guide capacitor *c*4 via a variable resistor *r*13 and is connected in parallel with the second guide capacitor *c*5 via a resistor *r*14 and a diode *n*9. The time constant provided by the second guide capacitor *c*5 and the resistor *r*14 is selected so small that said capacitor is discharged when the transistor *p*5 is in fully conductive condition whereby the discharge is substantially complete due to a sparkover in the filter F. On the other hand, the charging time constant determined by the second guide capacitor *c*5 and the resistor *r*15 is also so small that the voltage at said capacitor increases extremely rapidly to the voltage of the first guide capacitor *c*4 after the elimination of a sparkover in the filter F and the switching of the transistor *p*5 to its nonconductive condition.

The discharge of the first guide capacitor *c*4 during a sparkover of the filter F and during fully conductive condition of the transistor *p*5, is much slower and is determined by the resistance value of the variable resistor *r*13. Thus, after a sparkover in the filter F, the voltage at the first guide capacitor *c*4 is lower than that prior to the sparkover by only a small percentage adjustable by the variable resistor *r*13.

A sparkover of the filter F is measured by the glow lamp LA. The glow lamp LA is positioned above a photoelement *f* in a manner whereby the photosensitive region of said photoelement is exposed to light produced by said glow lamp. The photoelement *f* is connected in parallel with the base-emitter path of a transistor *p*1 via a diode *n*1. The transistor *p*1 and the diode *n*1 are so connected that during the irradiation of the photoelement *f*, the voltage at said photoelement controls said transistor to its fully conductive condition.

The transistor *p*1 and a transistor *p*2 function as a monostable flip-flop with resistors *r*2, *r*3 and *r*4 and a capacitor *c*1. When the glow lamp LA glows or produces light, that is, during normal operation of the filter, the transistor *p*1 is in its fully conductive condition and the transistor *p*2 is in its nonconductive condition. When there is a sparkover in the filter F, and during the occurrence of such sparkover, the glow lamp LA is extinguished or quenched and the transistor *p*1 is switched to its conductive condition. The transistor *p*2 is then switched to its fully conductive condition. The capacitor *c*1, which was charged via the resistors *r*4 and *r*2 and the transistor *p*1, discharges via the transistor *p*2, a diode *n*3, the diode *n*2 and the resistor *r*2 thereby maintaining, regardless of the operational condition of the filter F, the transistor *p*1 in its nonconductive condition. The full control of the transistor *p*2 is thereby maintained, regardless of the operational condition of the filter F, for a specific period determined by the time constant of the discharge circuit.

The base electrode of the transistor *p*5 is connected to the collector electrode of the transistor *p*2 via a resistor *r*9 and a capacitor *c*3 connected in series circuit arrangement with each other. The base electrode of the transistor *p*5 is connected to the negative polarity terminal N via a resistor *r*19. A resistor *r*10 is connected in parallel with the series circuit arrangement of the resistor *r*9 and the capacitor *c*3. When the transistor *p*2 is in its nonconductive condition, during normal operation of the filter F, the capacitor *c*3 is charged to a voltage having the indicated polarity. When the transistor *p*2 is in its fully conductive condition, the capacitor *c*3 may discharge via the transistor *p*2, a diode *n*3, the emitter-base path of the

transistor *p5* and the resistor *r9*. The transistor *p5* is thus always in its fully conductive condition simultaneously with the transistor *p2*. The discharge circuit of the capacitor *c3* is preferably so rated that the fully conductive condition of the transistor *p5* is not terminated prior to the termination of the flip-flop reset time of the monostable flip-flop circuit.

Each of the transistors *p1*, *p2*, *p3*, *p7*, *p8* and *p10* is an NPN-type transistor. Each of the transistors *p4* and *p5* is a PNP-type transistor. A transistor *p6* is an NPN-type transistor. The control path of the transistor *p5* is connected in parallel with the control path of the transistor *p6*. The emitter-collector path of the transistor *p6* is connected between the positive polarity terminal P and the intermediate terminal M via a resistor *r12*. The output terminal L of the control unit S*t*, connected to the control system I, is connected to the collector electrode of the transistor *p6*.

A voltage divider *r4*, *r10*, *r19* is so rated that the voltage applied to the control path of the transistor *p6* when the transistor *p2* is in its nonconductive condition, is sufficient to switch the transistor *p6* to its fully conductive condition. The transistor *p5* is then in its nonconductive condition. The base electrode of the transistor *p6* is coupled to the positive polarity terminal P via a diode *n8* and the resistor *r8*. The resistance values of the resistors *r8* and *r6* are so rated that the potential at the junction point of said resistors is such that the diode *n8* is in its nonconductive condition. This occurs during the illustrated position of a reversing switch *s* shown in FIG. 2, or when the transistor *p10* is in its fully conductive condition. The diode *n8* is in its conductive condition when the reversing switch *s* is in its position not shown in FIG. 2 and the transistor *p10* is in its nonconductive condition.

In order to determine a metallic short circuit in the filter F, the control unit S*t* includes a relay R having a working contact. The relay R is coupled between the positive and negative polarity terminals P and N via the emitter-collector path of a transistor *p3*, a diode *n5* and the reversing switch *s*. The base electrode of the transistor *p3* is connected to the collector electrode of the transistor *p2* via resistors *r5* and *r7* and a diode *n7*. The transistor *p3* is thus switched to its fully conductive condition when the transistor *p2* is switched to its conductive condition, during normal operation of the filter F.

A capacitor *c2* is connected between a common point in the connection between the resistors *r5* and *r7* and the emitter electrode of the transistor *p3*. The capacitor *c2* has a relatively high capacitance of a magnitude which determines, together with the resistance value of the resistor *r5*, the time which elapses between a short circuit in the filter F, the transistor *p2* being in its fully conductive condition, and the deenergization of the relay R.

The collector electrode of the transistor *p8* is connected to the collector electrode of the transistor *p2* via a diode *n11* and a resistor *r21* connected in series circuit arrangement. The collector electrode of the transistor *p8* is also connected to the emitter electrode of the transistor *p3* via a diode *n12* and a resistor *r22*. The emitter electrode of the transistor *p3* is connected to the base electrode of the transistor *p8* via a resistor *r23*. The resistor *r21* is rated at approximately the same resistance value as the resistor *r4*, so that when the transistor *p2* is in its nonconductive condition, and the transistor *p8* is in its fully conductive condition, the approximate potential of the intermediate terminal is applied to the collector electrode of the transistor *p2*. This prevents the capacitor *c3* from being charged while the transistor *p8* is in its fully conductive condition, during the increasing of the voltage at the filter F, following the switching of said transistor to its conductive condition. The periodic extinguishing of the glow lamp LA, when the transistor *p2* is in its fully conductive condition, due to the ripple or pulsation factor of the filter voltage during the increase thereof, may therefore not result in a voltage drop during such period. A control current is therefore supplied to the transistor *p6* via the resistor *r8* and the diode *n8*, if the reversing switch *s* is in its condition opposite that shown in FIG. 2 and the transistor *p10* is in its nonconductive condition.

The resistance values of the relay R and of the resistor *r22* are so rated that the emitter electrode of the transistor *p3* is sufficiently negative during such condition of operation that the diode *n5* is switched to its nonconductive condition and the transistor *p3* remains in its fully conductive condition.

The reversing switch *s* functions to maintain a predetermined initial condition during the commencement of the installation. In the position of the reversing switch *s* shown in FIG. 2, the base electrode of the transistor *p8* is connected to the negative polarity terminal N via the resistor *r23* and the diode *n5*, so that said transistor is switched to its nonconductive condition. On the other hand, the transistor *p4*, which is connected in parallel with the first guide capacitor *c4*, is in its fully conductive condition, since the base electrode of said transistor is connected to the negative polarity terminal N via the resistor *r6* and the diode *n6*. Since no voltage is applied to the filter F, the transistors *p2* and *p5* are in their fully conductive condition. The transistor *p6* is in its nonconductive condition and a cutoff signal is supplied to the terminal L of the control unit S*t*. The first and second guide capacitors *c4* and *c5* are discharged.

When the reversing switch *s* is in its position shown in FIG. 2, the thyristor *p9* is quenched, extinguished or switched to its nonconductive condition, after the installation is switched off.

To initiate the installation the reversing switch *s* is moved into its second switching position, opposite to that shown in FIG. 2, in which the cathodes of the diodes *n5* and *n6* are connected to the intermediate terminal M. The junction point of the resistors *r6* and *r8* thus becomes so positive that the transistor *p4* is switched to its nonconductive condition and the transistor *p6* is switched to its conductive condition. This eliminates the cutoff signal supplied to the terminal L of the control unit S*t*, so that the control system I (FIG. 1) supplies control pulses to the control circuit S (FIG. 1). The phase position of the control pulses supplied to the control circuit S by the control system I depends upon the control voltage U_{MA} at the second guide capacitor *c5*.

The transistor *p8* is supplied with a control current which switches it to its fully conductive condition, via the transistor *p3* and the resistor *r23*. The first and second guide capacitors *c4* and *c5* are therefore charged to a voltage of the polarity indicated in FIG. 2, via the resistor *r20*, the diode *n10*, the transistor *p8* and the diode *n13*. The charging time constant has a very low value, since the filter voltage, which depends upon the voltage at the second guide capacitor *c5*, is to obtain the breakthrough value as soon as possible, following the switching on of the installation.

As soon as the transistor *p8* is in its conductive condition, after the reversal of the reversing switch *s*, a current also flows via the resistors *r4* and *r21* and the diodes *n11* and *n13*. At the aforedescribed rating of the resistors, this means that the potential at the collector electrode of the transistor *p2* corresponds approximately to the potential of the intermediate terminal M, regardless of the operating condition of the filter F and the condition of the monostable flip-flop or multivibrator circuit. Despite this, the transistor *p3* is supplied with a control current via the diode *n7*, the resistor *r7*, the resistor *r5*, the resistor *r22*, the diode *n12*, the emitter-collector path of the transistor *p8* and the diode *n13*, since the emitter potential of the transistor *p3* is more negative at the aforedescribed rating of the relay R and the resistor *r22* than the potential of the intermediate terminal M. The relay therefore remains in its energized condition.

During the rapid charging of the first and second guide capacitors *c4* and *c5* via the transistor *p8* in its conductive condition, the transistor *p6* is supplied a full control current, via the resistor *r8* and the diode *n8*. Thus, no cutoff signal is supplied to the terminal L of the control unit S*t*. The control system I (FIG. 1) therefore delivers control pulses to the control circuit S. The phase position of the control circuit therefore depends upon the control voltage U_{MA} at the second guide capacitor *c5*.

The increase of the voltage at the second guide capacitor *c5* and the corresponding increase of the filter voltage causes the filter current to increase also. The voltage derived at the resistor *r26* thus also increases. At a specific value of the voltage at the resistor *r26*, which is the reference value of the filter current, the Zener diode *n14* is switched to its conductive condition and conducts current and the transistor *p10* and the thyristor *p9* are switched to their fully conductive condition. Thence the current through the relay R flows through the thyristor *p9*, via the transistor *p3* and the resistor *r23*. The transistor *p8* is switched to its nonconductive condition, since the control path of said transistor is short-circuited by the transistor *p9*. This terminates the exponential rapid charging of the first and second guide capacitors via the transistor *p8* and the output signal provided by the monostable multivibrator via the resistor *r21* and the diode *n11*.

The thyristor *p9* remains in its conductive condition until the reversing switch *s* is reversed in position or the installation is switched off. Regardless of the conductive condition of the transistor *p10*, the thyristor *p9* remains in its fully conductive condition. The first and second guide capacitors *c4* and *c5* may therefore be charged with a constant current during operation, only via the transistor *p7* and the resistor *r18*. The charge of the guide capacitors *c4* and *c5* is substantially independent of the ambient temperature, due to the diode *n13* coupled to the base electrode or control circuit of the transistor *p7*. This is of considerable importance when the time constant is very large. The control circuit of the transistor *p7* is of relatively low resistance, so that it is easily possible to position the variable resistor *r17* far away from the remainder of the installation, on a control board.

If the filter current exceeds the reference value during operation, the transistor *p10* and the transistor *p4* are temporarily in their fully conductive condition, so that the first and second guide capacitors *c4* and *c5* are slightly discharged. The filter voltage therefore decreases. The filter current again decreases to a value less than the reference value and the transistors *p10* and *p4* are switched to their nonconductive condition. The voltage of the first and second guide capacitors *c4* and *c5* and of the filter F thereafter slowly commences to increase linearly. The filter current is limited in this manner to the reference value, without a voltage-dependent decrease, during the time that no sparkover occurs in the filter F.

During a sparkover in the filter F, the transistor *p5* is switched to its fully conductive condition by the discharge of the capacitor *c3*, regardless of the magnitude of the filter current. The first guide capacitor *c4* is thereby discharged, via the resistor *r13*, by a specific, relatively small, amount. The second guide capacitor *c5* discharges almost completely, via the resistor *r14* and the diode *n9*. Furthermore, when the transistor *p5* is in its fully conductive condition, the transistor *p6* is switched to its nonconductive condition, so that a control pulse is not supplied to the control circuit S (FIG. 1) due to the supply of a cutoff signal to the terminal L of the control unit S*t*.

Upon the termination of the reset time of the monostable flip-flop circuit, the transistor *p5* is switched to its nonconductive condition and the second guide capacitor *c5* is charged relatively rapidly to the voltage of the first guide capacitor *c4*. The filter voltage increases correspondingly rapidly, since the transistor *p5* is in its conductive condition. Therefore, there is no longer a cutoff signal at the terminal L. The rate of charging of the second guide capacitor *c5* is adjusted to the installation in a manner whereby the filter voltage increases as rapidly as possible without varying abruptly the value determined by the first guide capacitor *c4*.

During the exponential charging of the first and second guide capacitors *c4* and *c5*, with the transistor *p8* in its fully conductive condition, the transistor *p5* may not be supplied with a control current via the resistor *r18*. This is due to the fact that the transistor *p6* is supplied with a control current for switching it to its fully conductive condition, via the resistor *r8* and the diode *n8*, so that the voltage applied to the base-emitter path of the transistor *p6* is applied as a blocking bias voltage to the control path of the transistor *p5*. The control current for the transistor *p6*, via the resistor *r8* and the diode *n8*, is omitted, however, if the filter current reaches the value of the reference current at the end of the voltage increasing period and the transistor *p10* is thereby fully controlled or switched to its fully conductive condition. If there is no sparkover in the filter F at such time, and the transistor *p2* of the monostable flip-flop circuit is therefore in its nonconductive condition, the transistor *p6* is supplied with a full control current via the resistors *r4* and *r10* and is switched thereby to its fully conductive condition.

If, however, during the initial response of the transistor *p10* after the initiation of the installation a sparkover or a light arc occurs in the filter F, as a result of which the transistor *p2* is switched to its fully conductive condition, the transistor *p6* is not supplied with control current, either via the resistors *r4* and *r10* or the resistor *r8* and the diode *n8*, so that the transistor p6 is switched to its nonconductive condition and a cutoff signal is provided at the output terminal L for obstructing the control pulse provided for the control circuit F.

Simultaneously, the transistor *p5* is supplied with a full control current via the resistor *r19* to switch said transistor to its fully conductive condition. This assures the discharge of the second guide capacitor *c5*. A full control of the transistor *p5* by the capacitor *c3*, via the transistor *p2*, would not be possible, however, at the termination of the exponential charging of the guide capacitors, since the capacitor *c3* could not yet be charged due to the transistor *p8* being in its full conductive condition. Thus, although in the period following the exponential charging of the guide capacitors, a cutoff signal is provided at the output terminal L and the discharge of both said guide capacitors is effected by the transistor *p5* during each sparkover of the filter F, regardless of the filter current, a voltage drop in said transistor and the provision of a cutoff signal are initiated after the exponential charging, if a sparkover or a light arc is present in the filter and if the filter current has reached or exceeded the reference value.

The invention may also be utilized in installations for the control of an electron beam or an ion beam, for material processing.

While the invention has been described by means of a specific example and in a specific embodiment, we do not wish to be limited thereto, for obvious modification will occur to those skilled in the art without departing from the spirit and scope of the invention.

We claim:

1. A circuit arrangement for automatic control of the voltage of an electrical filter, said circuit arrangement comprising

a control circuit coupled to an electrical filter for changing the voltage of said filter;

a source of voltage coupled to said control circuit;

a control system having an input coupled to said source of voltage, input means and an output connected to said control circuit for supplying to said control circuit a control magnitude, said control magnitude depending upon a control voltage supplied to the input means of said control system;

a glow lamp;

a voltage divider connecting said glow lamp in parallel with said filter; and

a control unit having an input coupled to said source of voltage and output means coupled t the input means of said control system, said control unit comprising a source of DC voltage, a guide capacitor, a charging circuit connecting said guide capacitor to said source of DC voltage whereby the control voltage supplied to said control system is produced by said control unit in accordance with voltage of said guide capacitor, a discharging circuit connected in parallel with said guide capacitor and including a controllable resistor having a resistance value dependent upon the voltage of said filter, a photoelement having a photosensitive area provided in operative prox-

imity with said glow lamp in a manner whereby light produced by said glow lamp impinges upon the photosensitive area of said photoelement, and circuit means coupling said photoelement to said discharging circuit for supplying a control signal dependent upon the irradiation of the photosensitive area of said photoelement whereby said control signal controls the controllable resistor of said discharging circuit to a low resistance value when said glow lamp fails to glow and controls said controllable resistor to a high resistance value when said glow lamp glows.

2. A circuit arrangement as claimed in claim 1, wherein said control unit further comprises a reversing switch, a switching component having a switching condition which depends upon the switching position of said reversing switch and the magnitude of current flowing through said filter, said switching component being in its conductive condition only during the time between the energization of said circuit arrangement, with the assistance of said reversing switch, and the time during which the current flowing through said filter reaches a critical value for the first time after the energization of said circuit arrangement by said reversing switch, said switching component being connected in a manner whereby said control signal is ineffective when said switching component is in its nonconductive condition.

3. A circuit arrangement as claimed in claim 2, wherein said control unit further comprises auxiliary circuit means connecting said switching component in parallel to the charging circuit of said guide capacitor.

4. A circuit arrangement as claimed in claim 2, wherein said control unit further comprises a capacitor, a resistor, a monostable multivibrator having a pair of input and output transistors of the same conductivity type and the controllable resistor of said control unit comprises a first transistor having a base-emitter path coupled via said capacitor and said resistor to the output of said monostable multivibrator whereby when said glow lamp glows, the input transistor of said monostable multivibrator is in its fully conductive condition, a resistor, a decoupling diode, a second transistor, the output of said monostable multivibrator being connected to the negative polarity terminal of said source of DC voltage via said resistor, decoupling diode and the emitter-collector path of said second transistor, said switching component comprising said second transistor whereby when said second transistor is in its fully conductive condition approximately the same potential is applied at the output of said monostable multivibrator as at the extinguished glow lamp, a third transistor having a control path connected in parallel with said first transistor and a base electrode of the third transistor, a reversible voltage divider, a diode connects the base electrode to said reversible voltage divider and conducting the control current of said third transistor, the control current of said third transistor flowing through said reversible voltage divider as long as the current flowing through said filter is below the critical value and said first transistor is in a condition other than its fully conductive condition.

5. A circuit arrangement as claimed in claim 4, wherein said control unit further comprises a fourth transistor of the same conductivity type as the pair of transistors of the monostable multivibrator, said fourth transistor having a collector electrode, a relay having an energizing winding connected to the collector electrode of said fourth transistor, a control circuit for said relay winding including the base-emitter path of said fourth transistor, said base-emitter path being connected to said relay winding, a decoupling diode connecting the control circuit of said relay in parallel with the output of said monostable multivibrator in a manner whereby when the glow lamp glows and said second transistor is in its nonconductive condition a control current flows, a resistor and a decoupling diode, said fourth transistor having an emitter electrode connected to the collector electrode of said second transistor, the emitter electrode of said fourth transistor having a potential of a magnitude which is such that when said second transistor is in its conductive condition said fourth transistor remains in its fully conductive condition.

6. A circuit arrangement for automatic control of the voltage of an electrical filter, said circuit arrangement comprising

a control circuit coupled to an electrical filter for changing the voltage of said filter;

a source of voltage coupled to said control circuit;

a control system having an input coupled to said source of voltage, input means and an output connected to said control circuit for supplying to said control circuit a control magnitude depending upon a control voltage supplied to the input means of said control system; and

a control unit having an input coupled to said source of voltage and output means coupled to the input means of said control system, said control unit comprising a source of DC voltage, a guide capacitor, a charging circuit connecting said guide capacitor to said source of DC voltage whereby the control voltage supplied to said control system is produced by said control unit in accordance with the voltage of said guide capacitor, a discharging circuit connnected in parallel with said guide capacitor and including a controllable resistor having a resistance value dependent upon the voltage of said filter, and cutoff circuit means for supplying a cutoff signal to the input means of said control system, said control system controlling said control circuit for interrupting the filter current without delay when a sparkover occurs in said filter.

7. A circuit arrangement as claimed in claim 6, wherein said control circuit comprises thyristor means and the control magnitude supplied by said control system controls said thyristor means, and wherein the cutoff circuit means of said control unit switches the thyristor means of said control circuit via said control system when a sparkover occurs in said filter.

8. A circuit arrangement as claimed in claim 7, wherein the cutoff circuit means of said control unit comprises a first transistor having an emitter-collector path and a control path, said cutoff signal being derived from a point in the emitter-collector path of said first transistor, a second transistor of complementary type to said first transistor having a control path connected in parallel with the control path of said first transistor, the controllable resistor of said discharging circuit comprising the control path of said second transistor, a first voltage divider having a tap point, each of said first and second transistors having a base electrode connected to said first voltage divider, said first transistor being in its fully conductive condition during normal operation of said filter, a third transistor of the same conductivity type as said first transistor, said third transistor being in its nonconductive condition during normal operation of said filter and switching to its conductive condition upon the occurrence of a sparkover in said filter, said third transistor having an emitter electrode coupled to the emitter electrode of said second transistor, a capacitor, a resistor, said third transistor having a collector electrode coupled to the base electrode of said second transistor via said capacitor and said resistor, the collector electrode of said third transistor being connected to the tap point of said first voltage divider, said capacitor discharging via the control path of said second transistor when said third transistor is in its conductive condition whereby the discharging of said capacitor switches said second capacitor to its conductive condition, a reversing switch, a diode and a second voltage divider connected to the base electrode of said second transistor via said diode, said diode being connected with a polarity which is such that said second voltage divider is supplied a fully advanced control current via said reversing switch in an operating position of said reversing switch and said second transistor is in its nonconductive condition.

9. A circuit arrangement as claimed in claim 8, wherein said control unit further comprises a fourth transistor functioning with said third transistor as a monostable multivibrator, said capacitor and said discharging circuit having time constants which prevent the termination of the fully conductive condition of said second transistor prior to the termination of the reset condition of said monostable multivibrator.

10. A circuit arrangement as claimed in claim 8, wherein said control unit further comprises a diode connecting said second voltage divider to said reversing switch, a fifth transistor having an emitter-collector path connected to said second voltage divider via said diode, said reversing switch having an operable switching position wherein it connects said second voltage divider to said source of DC voltage, and wherein said circuit arrangement further comprises a current transformer connected between said source of voltage and said control circuit and having an output connected to the input of said control unit for supplying a signal to said control unit when the current flowing through said filter exceeds a predetermined critical value, the fifth transistor of said control unit being fully controlled by the signal supplied by said current transformer to said control unit.

11. A circuit arrangement as claimed in claim 10, wherein

said control unit further comprises a resistor, a second guide capacitor connected to said first-mentioned guide capacitor via said resistor, said control voltage being derived from said second guide capacitor, another resistor, the controllable resistor of said discharging circuit being connected in parallel with said second guide capacitor via said other resistor, the period of interruption of the filter current and the time constant of said second guide capacitor and said discharging circuit being adjusted to each other in a manner whereby upon the termination of the interruption said second guide capacitor is substantially completely discharged, said second guide capacitor and said resistor having a time constant which is such that the voltage of said filter increases as rapidly as possible without overshooting.

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