United States Patent [19]

Griswold et al.

[11] **3,723,827**

[45] **Mar. 27, 1973**

[54] **SELECTIVE AND SEQUENTIAL CONTROL SYSTEM**

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[73] Assignee: **Griswold Controls**, Santa Ana, Calif.

[22] Filed: **Feb. 11, 1972**

[21] Appl. No.: **225,460**

[52] **U.S. Cl.**.....**317/137**, 239/DIG. 15, 307/38, 307/41, 317/141 S, 317/142 R

[51] **Int. Cl.**.....**H01h 47/14**

[58] **Field of Search**.....317/141 S, 142 R, 137, 139, 317/140; 307/38, 41, 141, 141.4, 234; 340/147 R, 147 C, 157, 168 A, 167 R, 167 A; 239/63, 67, DIG. 15

[56] **References Cited**

UNITED STATES PATENTS

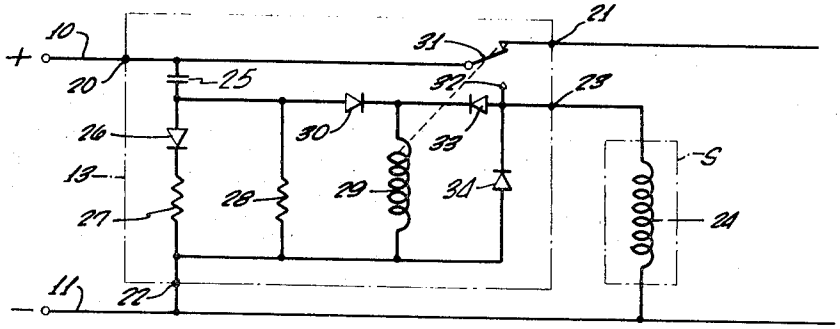
3,521,130	7/1970	Davis et al.	307/41 X
3,532,939	10/1970	Aviander	317/141 S
3,493,816	2/1970	Monigal et al.	317/148.5 B
2,139,117	12/1938	Gohorel	317/141 R

Primary Examiner—J. D. Miller
Assistant Examiner—Harry E. Moose, Jr.
Attorney—Allan R. Fowler et al.

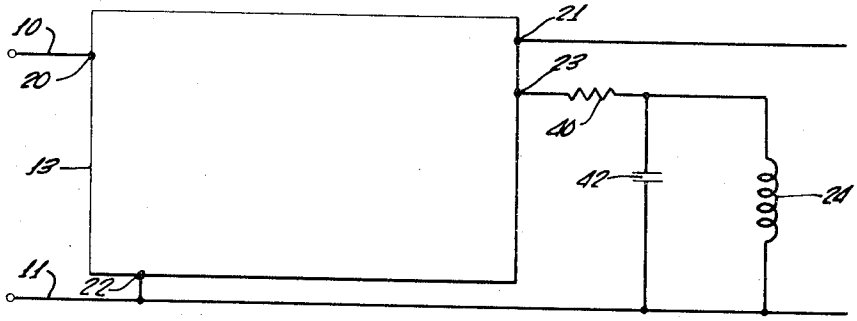
[57] **ABSTRACT**

A known system for controlling a plurality of stations, such as irrigating sprinkler valves, over a conductor pair for either selective or sequential activation includes a solenoid as the device to be activated at each station and requires short interruptions in the operating voltage at a control point to effect sequential activation of the stations, but for selective activation this same system utilizes two different voltage levels with short interruptions, a lower voltage being required to bypass unwanted stations and higher voltage built up at a controlled rate being required for selective activation of a station. An improvement in the known system includes delay means in association with the solenoids at the stations for delaying the response of the solenoids thereby simplifying the equipment the control point by permitting the use of only one voltage level, while avoiding activation of unselected stations.

23 Claims, 8 Drawing Figures



PRIOR ART



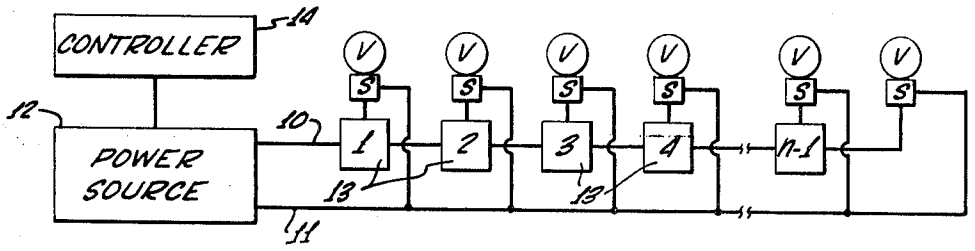


FIG. 1.
PRIOR ART

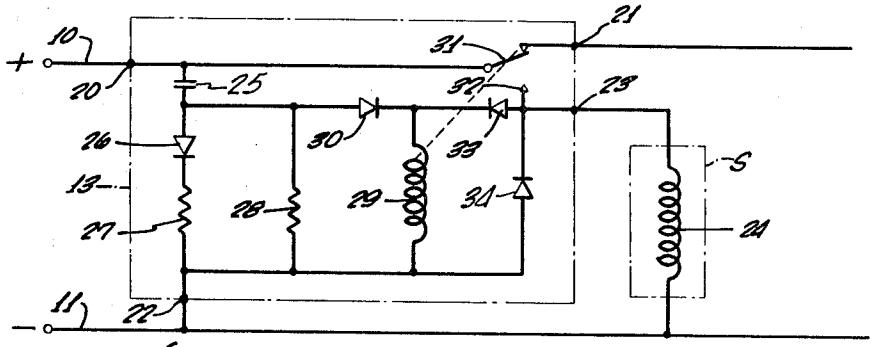


FIG. 2.
PRIOR ART

FIG. 3.

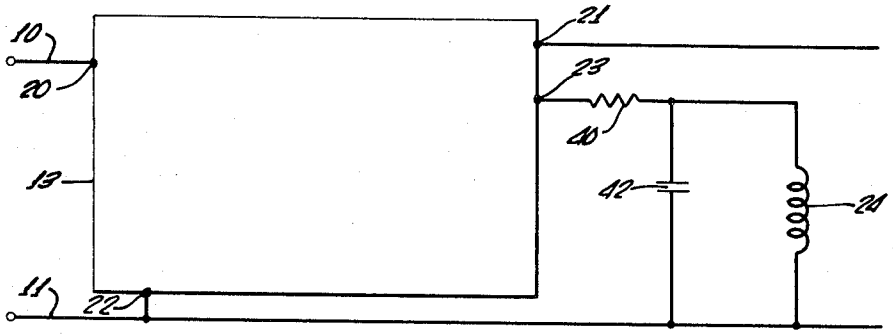


FIG. 8.

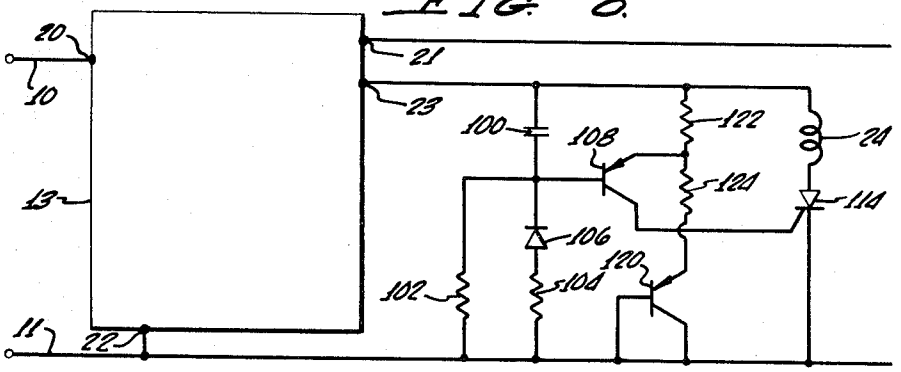


FIG. 4.

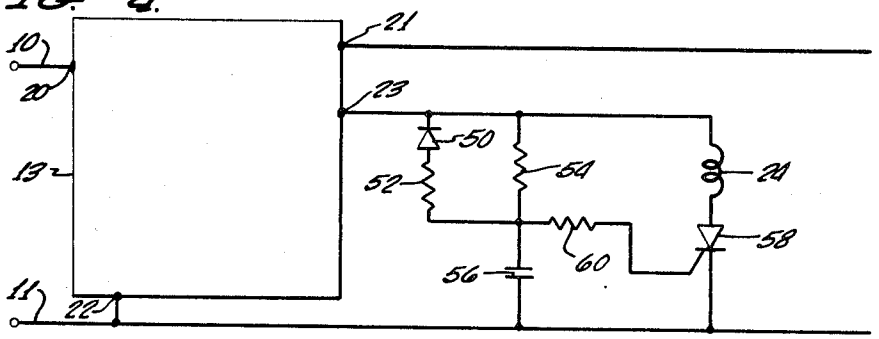


FIG. 5.

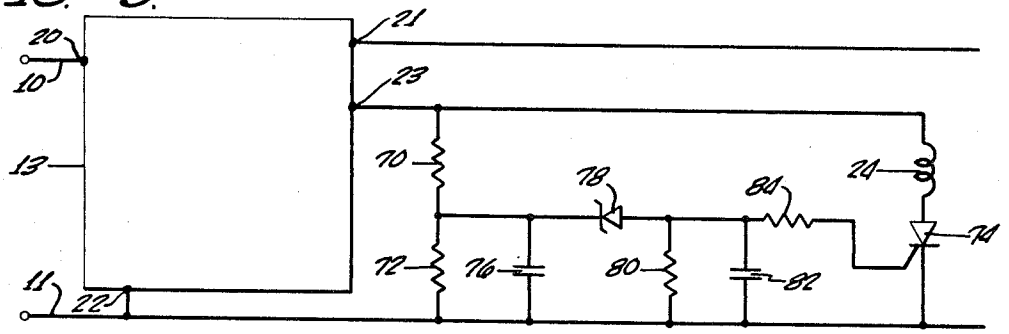


FIG. 6.

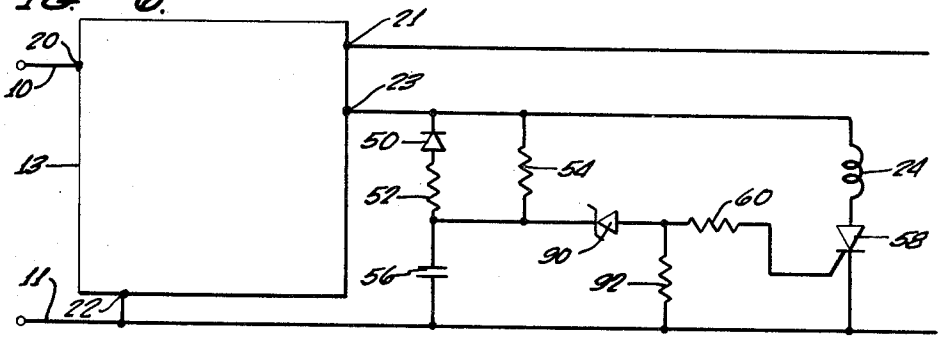
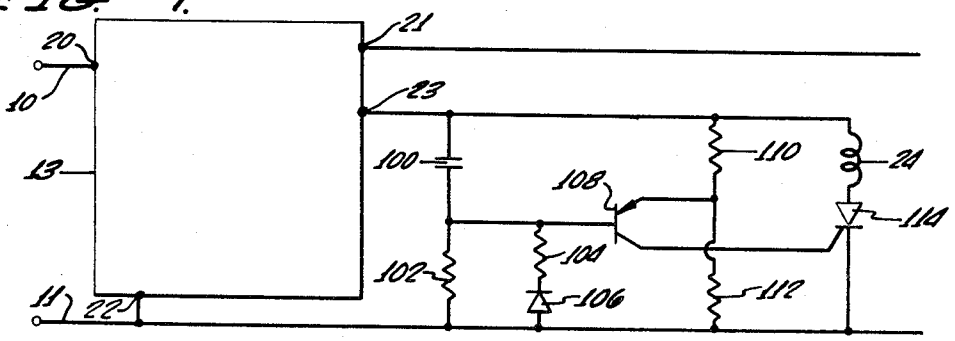


FIG. 7.



SELECTIVE AND SEQUENTIAL CONTROL SYSTEM

BACKGROUND OF THE INVENTION

In the maintenance of golf courses, one of the most frequently repeated activities is the watering of fairways and putting greens. It is usually done at off hours, such as at night when the course is not in use, and usually must be done in various areas of the course in succession, since it is generally not feasible to provide water supply facilities including pumping equipment adequate to operate all sprinkler heads concurrently. Accordingly, it is desirable to control the sequential watering of different areas on an unattended basis, while providing the capability of activation of individual sprinkler valves on a selective basis.

U.S. Pat. No. 3,521,130 granted July 21, 1970 to W. E. Davis et al. discloses a system having the intended purpose of accomplishing the aforementioned result. The system disclosed in this patent includes a master control station connected by a conductor pair to a first of a multiplicity of sprinkler valve control substations which are interconnected in tandem solely by conductor pairs. This arrangement avoids the provision of conductor pairs running from the control station to each of the substations, and accomplishes simplicity both in equipment and in the installation effort of laying underground wiring. A voltage source for operating control relays and valve operating solenoids at each of the substations is supplied from the master control station over the conductor pair, and the transfer of valve operating control from one substation to the next in the tandem array of substations is accomplished by interrupting and reapplying power over the conductor pair. Timing means at each substation is effective, once the substation has been activated and deactivated, to prevent reactivation of the substation. As long as the system is operated to activate the substations in succession along the line of their tandem interrelationship, a simple interruption and reapplication of operating voltage for a predetermined interval appears to accomplish the desired result.

However, this is not the case when the substations are to be activated on a selective basis. Such selective operation is accomplished by activating each station for a short period of time until the successive operation activates the selected station. Even such a short application and interruption of operating voltage is likely to cause unwanted momentary turn-on of the sprinkler head at the substation closest to the master control station circuitwise, as well as at others in succession until the substation that is intended to be selected has been activated. One undesirable result of this mode of operation can be the drenching of persons who may, for legitimate reasons, be in the vicinity of sprinkler heads that are not intended to be activated. A perhaps more serious result is that unwanted repetitious opening and closing of the sprinkler valves may cause excessive wear and greatly shorten the useful life of the valve.

A solution for this undesirable facet of the system shown in the patent has been suggested therein by arranging the master control station to apply voltage at two different levels to the conductor pair, a lower voltage that is ineffective to activate stations that are to be skipped and a higher voltage, reached by a time controlled rise from the lower voltage, adequate to activate

the stations that are to be selected. Manifestly, this complicates the equipment at the master control station, since it must provide for the application of both the lower and the higher voltages, as well as timing means for building up the voltage from the lower to the higher level.

An additional disadvantage of this prior art dual voltage system is the tendency of the non-selected solenoid valves to interfere with the low voltage signal pulses. The solenoids of the non-selected substations are intermittently connected across the signal lines during the sequencing operation. This connection may cause spurious signals on the signal line which interfere with the sequencing operation. Furthermore, this connection of non-selected solenoids may lower the voltage level of the signals at remote stations, thereby limiting the distance by which substations may be removed from the control station due to increased line-voltage drop.

A further disadvantage of the prior art dual voltage system is the requirement that the solenoid operated valves which are used must operate regardless of water pressure changes at the higher level voltage, but must never operate at the lower level voltage. The imposition of such a design requirement on a solenoid valve severely limits the operating efficiency of the valve, thus limiting the permissible distance between the control station and further removed substations.

SUMMARY OF THE INVENTION

The present invention represents an improvement on the system disclosed in the hereinbefore identified patent. It eliminates the need for supplying one or the other of two different voltages from the master control station to the conductor pair leading to the substations, and is operative instead on a single voltage, interrupted and reapplied to pass from one station to another, and applied steadily for the period of time that a sprinkler head valve is to be open. It avoids the necessity of providing at the master control station facilities for gradual buildup to the needed operating voltage.

The present invention accomplishes this simplification by slowing the response of the solenoids that operate the sprinkler head valves at the several substations. With this arrangement the bypassing of stations in the tandem array for the purpose of effecting the activation of a selected station may be accomplished by applying the full voltage to the conductor pair, to establish a condition of preparatory or partial activation in the case of each substation to be bypassed, interrupting the voltage before the solenoid becomes activated and reapplying the full voltage before the substation can return to its condition of complete deactivation, the substation then being incapable of responding to the successive applications of full voltage to a sufficient extent to produce operation of the solenoid.

With a mode of operation of the invention as described above, a number of beneficial results are achieved. The signaling pulses by means of which substations are bypassed to effect selective activation of a remote substation do not operate the valves at the bypassed stations. Thus excessive wear on the valves due to spurious operations is avoided. Because the solenoids do not become energized at stations that are being bypassed, the signaling pulse trains are not subjected to interference such as might result from heavy

current drain by a solenoid or inductively produced pulses. The same voltage level may be employed for signaling and for solenoid operation, as contrasted with a system requiring lesser and greater voltages, for signaling and solenoid operation respectively, and complications at the master control station due to the supplying of two different operating voltages are avoided. Moreover, with the solenoid isolated against response to the signaling pulses, the solenoid need not be required to discriminate in its operation between voltages below and above a predetermined level. This isolation also allows the use of solenoids which will operate at voltages substantially below the voltage supplied at the master control station. This feature permits the location of substations at greater distances along the two wire circuit, or the use of smaller diameter wires, since a higher line voltage drop can be tolerated.

DESCRIPTION OF THE DRAWINGS

For a complete understanding of the invention reference may be had to the following detailed description to be interpreted in the light of the accompanying drawings, wherein:

FIGS. **1** and **2** are respectively diagrammatic and schematic views derived from the hereinbefore identified patent and showing a system to which the present invention has been applied as an improvement; and

FIGS. **3–8**, inclusive, are schematic views showing six different embodiments of the present invention in association with a system of the kind represented in FIGS. **1** and **2**.

DETAILED DESCRIPTION

FIG. **1** of the drawings shows a plurality of sprinkler valves V, each of which is opened by energizing a corresponding one of solenoids S. An operating circuit for energizing the solenoids comprises a pair of wires or other conducting means **10** and **11** supplied with low voltage direct current from power source **12**. The power is applied to a plurality of control units **13** and to valve solenoids S by means of an essentially two-wire circuit which extends from the power supply, first to one control unit and corresponding valve solenoid, and then sequentially to other control units and their corresponding valve solenoids in the order of intended operation. The number of control units provided and required for the circuit shown is one less than the number of valves to be operated, or $n-1$, where n is the number of valves.

A controller **14** at a master control station is employed to periodically interrupt the power supply or line voltage as applied across conducting means **10** and **11** and, thereby, to "step" the system. The controller may be a simple manually operated switch but a preferred form of controller permits automatic interruption of the line current for predetermined short intervals after each sprinkler valve has been open for a predetermined interval. For example, a clock operated stepping switch such as a Buckner Model 4111 irrigation controller may be used.

FIG. **2** illustrates a preferred form of electromechanical control unit having essentially four terminal connections. An input terminal **20** connects the positive side of the D-C power source **12** through the back (normally closed) contacts of a relay to an output terminal **21**. Input terminal **20** of the first control unit of the series connects directly to the power source **12** through conductor **10**, whereas the input terminal **20** of subsequent control units in the series receives positive current from the power source **12** from the output terminal **21** of the preceding control unit in the sequence. A third or common terminal **22** of each control unit is connected to the negative conductor **11**, or ground, and control terminal **23** connects with the device to be operated. In the embodiment shown, terminals **23** connect with one side of solenoid coils **24**, respectively, each coil having its other side connected to negative conductor **11** or ground.

The circuit of each control unit more particularly comprises a capacitor **25** connected in series with a unidirectional current passing means, such as a diode **26**, and a resistor **27**, between terminals **20** and **22**. A second resistor **28** (having a relatively higher resistance than resistor **27**) is in parallel with diode **26** and resistor **27**, and is connected from the junction between capacitor **25** and diode **26** to terminal **22**. A relay coil **29** has one terminal connected to that junction through a diode **30** and has its other terminal connected to the terminal **22**. The values of resistors **27** and **28** are selected to develop, in cooperation with the diode **26**, a fast charging rate and a relatively slower discharge rate for capacitor **25**.

Application of line voltage to the control unit rapidly charges capacitor **25** through diode **26** and resistor **27**, paralleled by the diode **30** and winding of relay **29** in series, and the current through this branch is sufficient to energize relay coil **29**. The energized relay winding **29** disengages its contactor **31** from the back (normally closed) contact and engages it with the front (normally open) contact **32** to establish a holding circuit for the relay through the front contact **32**, a diode **33** and the winding of the relay **29** to terminal **22**, the diode **33** being connected in the path in its low impedance direction to pass the holding current. The contactor **31** also connects the terminal **20** through the front contact **32** of the relay **29** to terminal **23** to which is connected one terminal of the solenoid **24**. This connection therefore operates the sprinkler valve. The other terminal of the solenoid **24** is connected to terminal **22**. The winding of the solenoid **24** is shunted by a diode **34**, the function of which is to protect the front contacts **32** of the relay **29** from the inductive surge in the winding of the solenoid **24** when the contactor **31** disengages from the front contact **32**.

Thus, the initial charging of capacitor **25** immediately energizes the winding of relay **29** to open the normally closed electrical connection between the input and output terminals **20** and **21** of the control unit for the solenoid. The opening of the back contacts thus simultaneously disables subsequent control units, connects full line voltage across the winding of the solenoid **24** associated with the control unit that has been activated, and supplies a holding current through the winding of the relay **29** to maintain the solenoid **24** energized and the sprinkler valve open.

An interruption of the line current, for a time interval insufficient to discharge capacitor **25** completely, breaks the holding circuit for the relay **29** now closed through the front contacts **32** of the relay. This permits

the capacitor 25 to begin to discharge through the resistor 28. Reapplication of the full line voltage while the capacitor 25 is still partially charged and is incapable of passing sufficient charging current to effect the reoperation of the relay 29 will result in connection of the full line voltage through the back contacts of the relay 29 to terminal 21 and the succeeding control unit. On the other hand, an interruption of the line current for an interval of time sufficient to permit complete discharging of capacitor 25 will, in effect, reset the control unit, and the reapplication of full line voltage will then cause the circuit to again function as previously described.

In the complete system shown diagrammatically in FIG. 1, a brief interruption of power, of a duration less than the time for substantially complete discharging of a control unit capacitor 25, will advance the operating sequence by one control unit 13, the reapplication of full voltage operating the next control unit 13 in the sequence and disabling those beyond it in the tandem sequence. However, a longer interruption, one which is long enough for all charged capacitors 25 to discharge fully, resets the system. Reapplication of power then operates the first control unit 13 in the series.

Consideration will now be given to the operation of the system shown in FIG. 1, equipped with control units in accordance with FIG. 2, under the circumstance that it is desired to activate substation 3, shown in FIG. 1, on a selective basis and without activating the first and second substations. Because the circuitry of FIG. 2 requires a fast operating circuit for the relays 29 to avoid charging capacitors 25 in succeeding units, and since the relays 29 directly control the solenoids 24, the solenoids 24 will often operate and open the valves of non-selected stations, even though momentarily, with possible undesirable consequences. In order to overcome this undesirable aspect of the system, the patent discloses the provision of apparatus forming a part of the controller 14 for causing the application to conductors 10 and 11 of a fraction of the full voltage, in pulses, to bypass substations 13 in order to reach a substation 13 to be selectively activated, the fractional voltage being insufficient to effect the operation of the solenoid 24 at the substations 13 that are to be bypassed. The full voltage is applied for activating the substation 13 that is to be selected, and the valve solenoid 24 at that station 13 becomes operated.

As hereinbefore set forth, the present invention is directed to an improvement in the substation 13 equipment, which includes the solenoid 24 that operates the sprinkler valve, and which might operate any of a number of other types of functional devices to delay the operation of the solenoid 24 relative to the time of operation of the relay 29 which controls the solenoid, so that the master control station 14 may be simplified and operation of unselected stations avoided. Thus, by requiring only the connection and disconnection of a single-voltage power supply 12 for the conductor pair 10 and 11 for substation sequencing, power supply 12 complexities are avoided. In addition, this delayed solenoid operation alleviates the requirement that the solenoid be closely controlled to operate directly as a threshold device.

FIG. 3 shows one of six embodiments of the present invention. It corresponds with FIG. 2 in that the solid line rectangle 13 corresponds with the control unit 13 within the dotted line rectangle in FIG. 2. As will be noted in FIG. 3, the solenoid 24 is not connected directly to the terminal 23 and thus to the front contact 32 of the relay 29 as it is in FIG. 2, but is connected instead to the terminal 23 through a resistor 40. Additionally, a capacitor 42 is connected in parallel with the winding of the solenoid 24.

The resistor 40 and the capacitor 42 form a time delay network controlling the solenoid 24 and delaying the opening of its associated sprinkler valve. The time constants of the delay network comprising the resistor 40 and capacitor 42 may be chosen so that a voltage may be supplied from the master control station over the conductor pair 10 and 11, for a sufficient interval of time to cause the capacitor 25 to become fully charged and the relay 29 operated without operation of the solenoid 24. Interruption of the supply voltage then effects the release of the relay so that reapplication of the supply voltage will bypass the substation without any operation of the solenoid 24 to open its associated sprinkler valve. By the connection of power for a timed interval the bypassed station goes successively from selectable to selected and then to non-selectable condition.

When a substation is selected for activation, whether in a program of sequential activation of the stations or by a selective operation, the power source remains connected as a steady-state condition to maintain the relay 29 energized through its locking circuit and, after a delay caused by the resistor 40 and capacitor 42, which delay is of no consequence in a watering program, the solenoid 24 will operate to open its associated sprinkler valve. It will be understood that while the solenoid 24 is activated, there is a steady voltage drop across the resistor 40 so that the power source 12 must supply a voltage sufficient to maintain an operating current through solenoid 24 with a power loss represented by the voltage drop across the resistor 40. Moreover, in order that resistor 40 may have a reasonably small resistive value in order to minimize the wasted power, the capacitor 42 must be correspondingly large to produce the desired time delay. It then follows that the current required to charge the capacitor places even more stringent restrictions on the power supply. The embodiments of the invention described hereinafter provide for isolation of the solenoid from the time delay circuit and therefore permit the use of timing circuits having higher resistance and lower capacitance, with consequent efficiency in power utilization.

Referring now to FIG. 4, the circuitry for delaying the operation of solenoid 24 is somewhat more elaborate. It includes a diode 50, poled in its high impedance direction relative to the polarity of terminal 23, connected to the terminal 23, and a resistor 52 connected in series with the diode 50, these two components being paralleled by a resistor 54 having one of its terminals connected to the terminal 23 and the other connected to one terminal of a capacitor 56. The other terminal of the capacitor 56 is connected to terminal 22. The solenoid 24 is connected in series with a solid state switch device, shown herein as a silicon controlled rectifier 58, between terminals 23 and 22, with the rectifier 58 poled in a forward direction relative to the terminals 23 and 22. Finally, the gate terminal of the

silicon controlled rectifier **58** is connected through a resistor **60** to the junction of resistor **54** and capacitor **56**.

When terminal **23** becomes connected to conductor **10** as a result of the energization of the relay **29**, the capacitor **56** begins to charge through the resistor **54**. Because the gate of the silicon controlled rectifier **58** is connected through the resistor **60** to the upper terminal of capacitor **56**, the silicon controlled rectifier **58** does not become conductive the instant that terminal **23** becomes connected to the conductor **10**, but is delayed until the capacitor **56** has charged sufficiently to bring the gate of the silicon controlled rectifier **58** to the triggering potential relative to the negative potential on the cathode of the rectifier **58**. The winding of the solenoid **24**, being connected in series with the silicon controlled rectifier **58**, becomes energized only when the rectifier becomes conductive and the solenoid **24** operates and opens its sprinkler valve. The capacitor **56** must delay the gating of the silicon controlled rectifier **58** for an interval long enough for the energization and release of the relay **29** due to a momentary connection of power to the conductors **10** and **11** at the master control station when the station is to be bypassed.

Upon the disconnection of power from the conductors **10** and **11** after the selected substation shown in FIG. **4** has been in operation for the desired watering interval, current through the silicon controlled rectifier **58** and the winding of solenoid **24** is interrupted and the solenoid releases. Capacitor **56** has remained charged while the silicon controlled rectifier **58** was conductive. After either momentary or sustained energization of relay **29**, the capacitor **56** must be discharged to allow the relay circuit to again operate properly. The primary discharge path is through the cathode--anode junction in the silicon controlled rectifier, the diode **50** and resistor **52**. It will be noted that the diode **50** blocked the flow of charging current for capacitor **56** when power was first applied to conductors **10** and **11**, the flow of charging current passing through the resistor **54**, but that the diode is connected in the forward direction for the discharge current. This allows the selection of different charge and discharge rates for the capacitor **56**.

In the embodiment shown in FIG. **5** resistors **70** and **72** are connected in series between terminals **23** and **22** to form a voltage divider network. As in FIG. **4**, the winding of solenoid **24** and a silicon controlled rectifier **74** in the forward direction are connected in series between terminals **23** and **22**. The resistor **72** is shunted by a capacitor **76** and the junction of resistors **70** and **72** is connected to a threshold activated device, specifically to the cathode of a zener diode **78**, the anode of which is connected through a resistor **80** to the terminal **22**. The resistor **80** is shunted by a capacitor **82** and the interconnection point of the anode of the zener diode **28**, one terminal of the resistor **80** and one terminal of the capacitor **82** is connected through a resistor **84** to the gate of the silicon controlled rectifier **74**. Upon the connection of conductor **10** to terminal **23** the capacitor **76**, paralleled by resistor **72**, begins to charge through resistor **70** and the delay time in the charging of the capacitor is determined by the value of these three components.

The zener diode **78** isolates the gate terminal of the silicon controlled rectifier **74** from the rising potential across the capacitor **76** until the breakdown potential across the diode **78** is reached, at which time current flows through resistor **70**, the diode **78** and resistor **80**. The capacitor **82** protects the gate of silicon controlled rectifier **74** from line transients. The voltage across resistor **80** is applied through resistor **84**, which limits the gate current in the silicon controlled rectifier **74**, to the gate terminal of silicon controlled rectifier **74**, enabling the rectifier to pass operating current for the winding of solenoid **24**, thereby to open its associated valve. Upon the disconnection of power from the conductors of **10** and **11** at the master control station capacitors **76** and **82** discharge, the resistor **72** providing a discharging path for capacitor **76** and the resistor **80** providing a discharging path for the capacitor **82** and the zener diode **78** and the silicon controlled rectifier **74** return to their non-conductive states.

The embodiment of the invention shown in FIG. **6** differs from the one shown in FIG. **4** by the addition of two components, namely a zener diode and its bleeder resistor. Accordingly, the same reference numerals that appear in FIG. **4** have been applied to the corresponding components in FIG. **6**. The added components are the zener diode **90**, connected between the junction of resistor **54** and capacitor **56** and the series resistor **60** for the gate terminal of the silicon controlled rectifier **58**. The bleeder resistor **92** for the zener diode **90** is connected between the anode of the diode and terminal **22**.

The mode of operation of embodiment shown in FIG. **6** is generally the same as that of the embodiment shown in FIG. **4**. A more precise control of the activation of the silicon controlled rectifier **58** is achieved, however, because the gate terminal of the rectifier is isolated from the rising voltage across the capacitor **56** by the diode **90** and the silicon controlled rectifier is not influenced by the charging capacitor until the breakdown voltage across the zener diode **90** is reached, at which time the full voltage across the resistor **92** is applied between the gate and cathode terminals of the silicon controlled rectifier **58**.

The embodiment of the invention in FIG. **7** is similar to the circuit of FIG. **6**, the significant difference being the substitution of a different type of threshold device, a transistor, for the zener diode to control the gating of the silicon controlled rectifier. The network controlling the transistor comprises a capacitor **100** having one terminal connected to the terminal **23** and the other connected through a resistor **102** to terminal **22**. The resistor **102** is paralleled by a resistor **104** in series with a diode **106** which is connected in the high impedance direction relative to the negative polarity of terminal **22**. The junction of capacitor **100** and resistor **102** is connected to the base of the PNP type transistor **108**. It will be noted that the network comprising capacitor **100**, resistor **102**, resistor **104** and diode **106** are reversed in relation to the configuration of FIG. **6** in order to properly control the transistor. The proper biasing potential for the emitter of the transistor **108** is provided by a voltage divider comprised of the resistors **110** and **112** connected in series between terminals **23** and **22**. The collector of the transistor is connected directly to the gate terminal of a silicon controlled

rectifier **114** which is connected in series with the winding of the solenoid **24**.

In operation, the connection of power to terminals **23** and **22** will result in the charging of capacitor **100** through the resistor **102**. The voltage on the emitter of the transistor **108** is fixed as a fraction of the total input voltage and is determined by the relative values of resistors **110** and **112**. This is the reference trigger voltage. When the potential across the capacitor **100** becomes greater than the potential on the emitter, the transistor begins to conduct and thereby turns on the silicon controlled rectifier, which in turns passes current through the winding of the solenoid **24** to operate the solenoid. The transistor **108** produces a current amplification, so that the delay network comprising resistor **102** and capacitor **100** need not be capable of supplying the required gate current for the silicon controlled rectifier **114**. When the sprinkler valve is to be reclosed, power is disconnected from the conductors **10** and **11**, thus cutting off current through the solenoid **24** and the silicon controlled rectifier **114**. The capacitor **100** then discharges through resistor **104**, diode **106**, resistor **110** and resistor **112** in series.

FIG. **8** shows an embodiment which is similar to that of FIG. **7**, differing only in the provision of an additional transistor, but the difference is of considerable significance operationally. The same reference numerals shown in FIG. **7** have been applied to the corresponding components in FIG. **8**. The added transistor **120** is connected in series with resistor **124**, with its base and collector both connected to terminal **22**. Thus, when power is applied between conductors **10** and **11**, a predetermined voltage drop will develop across the transistor **120** and that voltage drop will be added to the voltage drop across the resistor **124**, thereby raising the biasing voltage applied to the emitter of the transistor **108**.

This circuit alleviates the problem of variations in the time delay due to changes in the voltage level applied to lines **10** and **11**. The switching threshold (S) of the transistor **108**, without the insertion of the transistor **120**, is equal to the voltage on the emitter of the transistor **108** plus the fixed voltage drop (e_1) in the emitter-base junction of the transistor **108**. The emitter voltage is maintained at a fixed percentage (%) of the voltage divider action of resistors **122** and **124**. Thus, without the transistor **120**, the switching threshold of transistor **108** is:

$$S = \%(E_1) + e_1$$

the voltage (F) on the base of the transistor **108**, at any given time after initiation of the charging sequence, is proportional to the applied voltage. Thus, after a specified charging time,

$$F = KE$$

since the transistor **108** will threshold when $F = S$, the time delay would be constant and independent of the applied voltage E, but for the voltage drop e_1. The transistor **120** offsets this voltage drop e_1 by elevating the voltage of the emitter of the transistor **108** by an equivalent fixed voltage. The circuit of FIG. **8** therefore energizes the solenoid **24** after a time delay which is independent of the voltage on lines **10** and **11**.

Test results with a circuit like the one shown in FIG. **7** show a delay of 7.2 seconds in the turning on of the silicon controlled rectifier **114**, whereas, with an input voltage of 30 volts, the delay in the turn on of the silicon controlled rectifier is only 5.4 seconds. With the circuit of FIG. **8**, including, as it does, the transistor **120**, and with the same range of voltages applied to the input, the delay time in the turning on of the silicon controlled rectifier **114** varies less than 5 percent. This is of significance when it is realized that, with substations scattered throughout a golf course and a conductor pair extending many hundreds of feet to connect all of them to the master control station, the voltage available at the remote substations may be considerably lower than the voltage applied to the conductor pair at the master control station.

Although the invention is described herein as an improvement on the prior art embodiment shown in FIG. **2**, it will be readily understood by those skilled in the art that this improvement may be used on any prior art two wire signal decoding system, including all of the embodiments shown in U.S. Pat. No. 3,521,130.

Likewise, although a feature of this invention is the ability to utilize only one voltage for signaling and operating the devices, it will be recognized that the invention described is compatible with the prior art master control station supplying two different voltage levels and a slow voltage rise to the operating level. However, the ability to operate in response to a single voltage level alleviates the requirement that the components of the substation circuitry within the rectangle **13** be capable of operating at a low voltage and still tolerate a higher voltage.

It should be noted that in order to provide surge protection for the silicon controlled rectifier in any of FIGS. **4** to **8** it may be desirable to connect in parallel with the solenoid **24** a diode of sufficient capacity to pass surge currents, and poled in the opposite direction relative to the operating voltage applied to the solenoid. Alternatively such protection may be afforded by connection across the solenoid of a shunt path comprised of a resistor in series with a capacitor.

It should also be noted that under certain operating conditions the low impedance discharge path through resistor **104** and diode **106** for capacitor **100** may not be required in the circuits shown in FIGS. **7** and **8**. The resistor **110** and the emitter-base junction of the transistor **108** may provide a relatively low impedance path by comparison with resistor **102**. The provision or omission of resistor **104** and diode **106** is dependent upon how short the discharge time for capacitor **100** must be in order for the system to operate.

What is claimed is:

1. The combination with a control system comprising:

a master control station having means for generating signaling pulses;

a plurality of substations connected serially to the master station over common circuitry and conditionable from a selectable state to a selected state to a non-selectable state in succession in the order of their serial relation to the master station in response to a succession of signaling pulses; and

an electro-responsive device at each substation operable by energy supplied from the master control station over said common circuitry;

of delay means associated with said electro-responsive device for precluding its operation in response to pulses failing to maintain the substation in its selected state for a predetermined interval.

2. A combination in accordance with claim 1 wherein:

the delay means comprises resistive and capacitive components.

3. A combination in accordance with claim 1 wherein the delay means comprises a capacitor connected in parallel with said electro-responsive device and a resistor in series with said paralleled capacitor and electro-responsive device.

4. A combination in accordance with claim 1 wherein the delay means comprises:

a resistor;

a capacitor connected to be charged through said resistor by a pulse received from the master control station by the substation; and

a switch connected in series with the electro-responsive device and operable in response to accumulation of a charge on said capacitor to a predetermined level.

5. A combination in accordance with claim 4 wherein the switch is a solid state device.

6. A combination in accordance with claim 5 in which the solid state switch is a silicon controlled rectifier.

7. A combination in accordance with claim 1 wherein the delay means comprises:

a resistor;

a capacitor connected to be charged through said resistor by a pulse received from the master control station by the substation;

a threshold-operable device connected to said capacitor to be operable in response to accumulation of a charge on said capacitor to a predetermined level; and

a switch connected in series with said electro-responsive device and operatively controlled by said threshold-operable device.

8. A combination in accordance with claim 7 wherein the threshold operable device is a solid state device.

9. A combination in accordance with claim 8 wherein the threshold operable device is a breakdown diode.

10. A combination in accordance with claim 8 wherein the threshold operable device is a transistor biased beyond cut-off.

11. A combination in accordance with claim 10 wherein potentials for both biasing and operating the transistor are supplied by the pulse received by the substation.

12. A combination in accordance with claim 7 wherein the threshold-operable device is a transistor having its base connected to said capacitor and has associated therewith:

a potential divider connected to apply to the emitter of the transistor a biasing voltage derived from the pulse received from the master control station by the substation and including as an element of the potential divider means for contributing a controlled voltage component to render the delay in the operation of said transistor relatively independent of the voltage magnitude of the received pulse.

13. A combination in accordance with claim 12 wherein the means for contributing the controlled voltage component is a solid state device developing across a junction therein a voltage drop substantially equaling the voltage drop developed across the emitter-base junction of said transistor.

14. In a selective remote control system:

a master control station having means for generating pulses of equal length and steady-state conditions all at a predetermined fixed electrical magnitude;

a plurality of substations;

a two-conductor control circuit for transmission thereover of said pulses and steady-state conditions, said control circuit connecting said master control station to all of said substations with the substations arranged in tandem along said control circuit;

an electro-responsive device at each substation;

signal responsive means at each substation operative in response to a pulse from the master control station for preparing a path for operation of the electro-responsive device and for disconnecting all stations beyond it in the tandem array from the master station;

means at each substation conditioned incident to operation of the signal responsive means thereat for precluding reoperation of said signal responsive means as long as pulses follow one another with predetermined intervening maximum intervals, whereby the signal responsive means at successive substations become operatively responsive to successive pulses; and

time delay means associated with said electro-responsive device for enabling its operation in response only to steady-state conditions.

15. A selective remote control system in accordance with claim 14 wherein the time delay means comprises only resistive and capacitive components.

16. A selective remote control system in accordance with claim 14 wherein the time delay means comprises:

resistive and capacitive means arranged for charging of the capacitive means through the resistive means; and

solid state means responsive to the charging of the capacitive means for causing the admission of current from said two-wire circuit to said electro-responsive device.

17. A selective remote control system in accordance with claim 14 wherein the time delay means comprises:

resistive and capacitive means arranged for charging of the capacitive means;

switch means for admitting operating current into said electro-responsive device from said two-wire circuit; and

threshold means responsive to the charging of said capacitive means to a predetermined level for operating said switch means.

18. A selective remote control system in accordance with claim 17 wherein said switch means is a solid state device.

19. A selective remote control system in accordance with claim 17 wherein said threshold means is a solid state device.

20. A method of selectively controlling from a master station a plurality of substations each having a functional device to be operated over a two-conductor

path with which the substations are associated in tandem relation which comprises:

generating at the master station pulses of at least a predetermined duration and the same electrical magnitudes and transmitting the pulses over the two-conductor path to condition the substations successively in the order of their positions along the two-conductor path for operation of their functional devices;

measuring the duration of a pulse received at each substation; and

energizing the functional device in response to persistence of said measuring step longer than said predetermined duration.

21. A method of selectively controlling from a master station a plurality of substations each having an electromagnetically operable functional device to be operated over a two-conductor path with which the substations are associated in tandem relation which comprises:

disconnecting all of the functional devices from the two conductor path;

generating at the master station pulses of at least a predetermined duration and the same electrical magnitudes and transmitting the pulses over the two-conductor path to condition the substations successively in the order of their positions along the two-conductor path for operation of their functional devices;

measuring the duration of a pulse received at each substation; and

reconnecting the functional device to the two conductor path at each substation in response to persistence of said measuring step longer than said predetermined duration.

22. A method of selectively controlling from a master station a plurality of substations each having a functional device to be operated over a two-conductor path with which the substations are associated in tandem relation which comprises:

generating at the master station pulses of predetermined duration and pulses of longer duration all at the same electrical magnitude and transmitting the pulses over the two-conductor path to condition the substations successively in the order of their positions along the two-conductor path for operation of their functional devices;

preliminarily conditioning each substation in response to a received pulse of said predetermined duration for selective actuation of its functional device; and

selectively activating the functional device at a preliminarily conditioned substation in response to a pulse of said longer duration.

23. A method of selectively controlling from a master station a plurality of substations each having a functional device to be operated over a two-conductor path with which the substations are associated in tandem relation which comprises:

generating at the master station pulses of predetermined duration and the same electrical magnitudes and transmitting the pulses over the two-conductor path to condition the substations successively in the order of their positions along the two-conductor path for operation of their functional devices;

energizing the functional device at a substation only in response to the steady state prolongation of the pulse.

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