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ALTERNATING RELAYS FOR EXTENDED LIFE OF RELAYS

Abstract

A system and method for including a processor having addressable memory, the processor in communication with two or more relays, where the processor is configured to: store a first state based on an order of two or more relays to be switched on; send one or more first signals to switch on a relay of two or more relays based on the stored first state; wait for a set time after sending each first signal of the one or more first signals; and update the first state based on the order the one or more first signals were sent.

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Background/Summary

FIELD OF ENDEAVOR
[0001] The invention relates to electrically operated switches and more particularly to relays.
BACKGROUND

[0002] Electrically operated switches such as electrical relays are used in a variety of systems, an example of which is in electric vehicle supply equipment (EVSE). Relays control electrical energy transfer between various components of an electrical system. Repeated use of a relay by turning the relay on and off, shortens the life of the relay. Premature failure of a relay in a system leads to premature failure of the system.

SUMMARY

[0003] Embodiments disclose a method and system for extending the useful life of electrical switches, such as relays, and the systems controlled by such switches. One embodiment comprises a system for controlling a plurality of electrical switches, each electrical switch having two or more operational states and responsive to control signals for changing between operational states. The system comprises a controller configured to generate control signals to selectively change the operational state of one or more of the electrical switches based on at least one of: a selected timing and a selected sequence. The system reduces early degradation of one or more of the electrical switches in relation to said plurality of electrical switches.

[0004] A system embodiment may include: a processor having addressable memory, the processor in communication with two or more relays, where the processor may be configured to: store a first state based on an order of two or more relays to be switched on; send one or more first signals to switch on a relay of two or more relays based on the stored first state; wait for a set time after sending each first signal of the one or more first signals; and update the first state based on the order the one or more first signals were sent.

[0005] In additional system embodiments, the processor may be further configured to: store a second state based on an order of two or more relays to be switched off; send one or more second signals to switch off a relay of two or more relays based on the stored second state; wait for a set time after sending each second signal of the one or more second signals; and update the second state based on the order the one or more second signals were sent.

[0006] In additional system embodiments, the set time may be greater than an operating time of each relay of the two or more relays. In additional system embodiments, the set time may be based on a transfer time of the two or more relays and a system power cycle time.

[0007] In additional system embodiments, the order of the two or more relays to be switched on may be in a variable sequence determined by the first state. In additional system embodiments, the two or more relays may be in an electric vehicle supply equipment (EVSE). In additional system embodiments, the processor may be further configured to: check a status of the two or more relays after the one or more first signals were sent.

[0008] In additional system embodiments, the stored first state may be configured to vary which relay of the two or more relays may be turned on as a first relay to be turned on, and where the stored first state may be configured to reduce early degradation of a relay of the two or more relays in relation to other relays of the two or more relays.

[0009] In additional system embodiments, the two or more relays comprise two relays, where a first first signal of the one or more first signals may be configured to turn on a first relay of the two or more relays based on the stored first state, where a second first signal of the one or more first signals may be configured to turn on a second relay of the two or more relays based on the stored first state. In additional system embodiments, the first first signal of the one or more first signals may be configured to turn on the second relay of the two or more relays based on the updated first state, and where the second first signal of the one or more first signals may be configured to turn on the first relay of the two or more relays based on the updated first state.

[0010] Another system embodiment may include a system for controlling a plurality of electrical switches, each electrical switch having two or more operational states and responsive to control signals for changing between operational states, the system comprising: a controller configured to generate control signals to selectively change the operational state of one or more of the electrical switches based on at least one of: a selected timing and a selected sequence; where the selective changing of the operational state of the one or more of the electrical switches may be configured to reduce early degradation of the one or more of the electrical switches in relation to said plurality of electrical switches.

[0011] In additional system embodiments, the controller may be further configured to generate control signals to selectively change the operational state of one or more of the electrical switches based on a selected timing as a function of the operational characteristics of one or more of the electrical switches. In additional system embodiments, the controller may be further configured to selectively change the operational state of one or more of the electrical switches based on a selected timing as a function of said operational characteristics including one or more of: power cycle time and switch transfer time.

[0012] In additional system embodiments, the controller may be further configured to generate control signals to selectively change the operational state of one or more of the electrical switches in a variable sequence. In additional system embodiments, the controller may be further configured to generate control signals to selectively change the operational state of one or more of the electrical switches in a variable sequence based on selected timing as a function of one or more of: power cycle time and switch transfer time.

[0013] In additional system embodiments, the controller may be configured to generate control signals to change the operational state of one or more of the electrical switches in an alternating sequence. In additional system embodiments, the controller may be further configured to change the operational state of one or more of the electrical switches in an alternating sequence based on selected timing as a function of one or more of: switch transfer time and system power cycle time.

[0014] In additional system embodiments, the controller may be further configured to change the operational state of each of the electrical switches based on a selected timing and selected sequence to prevent one or more of the electrical switches from early degradation in relation to the other electrical switches in the system.

[0015] Another system embodiment may include: a plurality of electrical switches, each electrical switch having two or more operational states and responsive to control signals for changing between operational states; a controller configured to generate control signals to selectively change the operational state of one or more of the electrical switches based on at least one of: a selected timing and a selected sequence, to reduce early degradation of one or more of the electrical switches in relation to said plurality of electrical switches.

[0016] Additional system embodiments may include: N relays; a state counter C that cycles through counts 1, 2, . . . , N, 1, 2, . . . , N, 1, 2, . . . , N, where the controller may be further configured such that in a power cycle: in a control state C, upon receiving a power on signal, a relay C may be turned on first, and then subsequent relays may be turned on in sequence after a set wait time has passed for each delay; in the control state C, upon receiving a power off signal, relay C may be turned off first, and then subsequent relays may be turned off in sequence after a set wait time has passed for each; the state counter may be incremented by one, such that when C=N, the state counter C may be reset to 1.

[0017] In additional system embodiments, the set wait time may be a function of at least one of: relay transfer time and system power cycle time.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principals of the invention. Like reference numerals designate corresponding parts throughout the different views. Embodiments are illustrated by way of example and not limitation in the figures of the accompanying drawings, in which:

[0019] FIG. **1** depicts an exemplary system for controlling power between a utility and an electric vehicle, which includes a controller configured to selectively change the operational state of one or more of the electrical switches such as relays, to reduce early degradation of one or more of the relays in relation to other relays in the system;
[0020] FIG. **2** depicts a cross-sectional side view of an embodiment of an EVSE and power outlet and protective enclosure;
[0021] FIG. **3** is a block diagram illustrating one embodiment of an EVSE system;
[0022] FIG. **4** is a block diagram illustrating a system including at least a controller configured to selectively change the operational state of one or more relays, such as alternating relays to extend life of relays, according to one embodiment disclosed herein;
[0023] FIG. **5** is a graphical representation of electrical and control signals in the system from FIG. **4**, according to one embodiment;
[0024] FIG. **6**A depicts a flow chart of a method embodiment of changing operation state of two or more relays to on, according to one embodiment;
[0025] FIG. **6**B depicts a flow chart of a method embodiment of changing operation state of two or more relays to off, according to one embodiment;
[0026] FIG. **6**C depicts a flow chart of a method embodiment of changing operation state of two relays to on, according to one embodiment;
[0027] FIG. **6**D depicts a flow chart of a method embodiment of changing operation state of three relays to on, according to one embodiment;
[0028] FIG. **6**E depicts a flow chart of a method embodiment of changing operation state of four relays to on, according to one embodiment;
[0029] FIG. **7** illustrates an example of a top-level functional block diagram of a computing device embodiment;
[0030] FIG. **8** is a high-level block diagram showing a computing system comprising a computer system useful for implementing an embodiment of the system and method disclosed herein;
[0031] FIG. **9** shows a block diagram of an example system in which an embodiment may be implemented; and
[0032] FIG. **10** depicts an illustrative cloud computing environment, according to one embodiment.

DETAILED DESCRIPTION

[0033] The following description is made for the purpose of illustrating the general principles of the embodiments disclosed herein and is not meant to limit the concepts disclosed herein. Further, particular features described herein can be used in combination with other described features in each of the various possible combinations and permutations. Unless otherwise specifically defined herein, all terms are to be given their broadest possible interpretation including meanings implied from the description as well as meanings understood by those skilled in the art and/or as defined in dictionaries, treatises, etc.

[0034] Embodiments described herein disclose a method and system for extending the useful life of relays and the systems controlled by such relays. A relay is an electrically operated switch. An example relay comprises an electrical coil, which upon receiving an electric control signal, converts the signal to a mechanical action to move moveable electrical contacts to open and close the electric circuit. A relay may include one or more input terminals for one or more control signals to change an operational state of the relay, and further include operating contact terminals for conducting electricity from a power source therethrough. The relay may include a number of contacts in multiple operational states (e.g., contact forms), which in response to the coil change its operational state such as: making contact to close a circuit, breaking contact to open a circuit, or combinations thereof.

[0035] Each relay has operational characteristics including operation time, transfer time, and release time. The operating time of a relay comprises the elapsed time from the initial application of power to the coil, until the closure of the normally open contacts. As such, the operating time of a relay comprises the time for the magnetic field to form (so the switch contact is attracted), plus the transfer time of the moveable contact (from its open to its closed position). The release time of a relay comprises the elapsed time from the initial removal of coil power until the reclosure of the normally closed contacts (this time does not include bounce). As such, the release time of a relay comprises the time for the magnetic field to weaken and cease (so the switch is no longer attracted), plus the transfer time of the moveable contact (from its closed to its open position). The electrical system, including the relays, has an associated power cycle time period which is the time between one power on, to the next, or from one power off to the next.

[0036] An example use of relays is in an electrical system utilizing two or more relays for delivering electrical power to an electrical load. In one example, an electrical load comprises an electrical device or component that consumes electrical energy and converts that energy into another form (e.g., resistive loads, inductive loads, capacitive loads, etc.).

[0037] In system operation, typically control signals to turn two or more relays on/off are sent to the relays at the same time. In actual use, even similar relays do not operate at the same speed in response to the control signal to open or close the relay contacts. Although all the relay coils are energized and de-energized at the same time, no two relays have exactly the same response time. There will always be a slight difference in the closing and opening times of the relays. If one relay consistently closes last, it will experience more arcing than a relay that closes first. Arcing is the primary cause of relay electrical contact wear and degradation and even a slight increase in contact resistance can significantly increase the heat generated due to power loss at the contact, negatively affecting the system. This is because in practice the order of opening and closing relays in a system is in a fixed or static sequence (i.e., one relay always being faster or slower to turn on/off).

[0038] For example, in a system utilizing two or more relays in an electrical circuit to deliver electrical power from a power source to a load, control signals (i.e., actuation signals) to turn the relays on are sent to the relays at the same time to close the circuit between the power source and the load, allowing the flow of electrical current between the power source and the load. However, one of the relays may be slower to turn on (and/or turn off) than other relays. Whichever relay turns on slower, generally consistently turns on slower, which results in extra electromechanical forces and electrical arcing being applied to that relay, reducing the life cycle of that relay and the system as a whole.

[0039] Both when a relay turns on and turns off, there is some level of stress and damage applied to the relay. In a system having two or more relays, when a controller sends a signal to turn relays on and/or off at the very same time, one of the relays will consistently turn on and/or turn off faster than the other relay or relays. A relay that turns off faster generally consistently turns off faster. The first relay to turn off or release (e.g., break contact) is the relay that is exposed to the brunt of electromechanical force on the release cycle. Such repeated exposure of a relay among several relays causes early failure of that relay.

[0040] The disclosed embodiments herein provide a controller and method for selected timing of control signals to multiple relays in a system, such that certain relays (e.g., slower, or faster relays) would not absorb a larger portion of electromechanical energy from turning on or off, compared to other relays. In another embodiment, a controller and method disclosed herein provide selected timing of control signals to multiple relays to substantially equally distribute electromechanical energy from turning on or off among relays in a system. In another embodiment, a controller and method disclosed herein provide selected timing of control signals to multiple relays such that relays are turned on/off in a changing sequence. In another embodiment, a controller and method disclosed herein provide selected timing of control signals to multiple relays such that the order (i.e., sequence) of opening and closing relays is not in a static sequence. In another embodiment, a controller and method disclosed herein provide selected timing of control signals to multiple relays such that the order of opening and closing relays is in an adjustable sequence. In another embodiment, a controller and method disclosed herein provide selected timing of control signals to multiple relays such that the order of opening and closing relays is in a variable sequence. In another embodiment, a controller and method disclosed herein provide selected timing of control signals to multiple relays such that the order of opening and closing relays is in an adaptable sequence. In another embodiment, a controller and method disclosed herein provide selected timing of control signals to multiple relays such that the order of opening and closing relays is in a dynamic sequence.

[0041] In another embodiment, a controller and method disclosed herein provide selected timing of control signals to multiple relays such that the order (sequence) of changing the operational state of the relays is a function of the operational characteristics of one or more of the relays.

[0042] In another embodiment, a controller and method disclosed herein provide changing the operational state of the relays as a function of the operational characteristics of one or more of the relays. In another embodiment, a controller and method disclosed herein provide a selected timing for changing the operational state of the relays, wherein the selected timing is a function of the operational characteristics of one or more of the relays in the system. In another embodiment, a controller and method disclosed herein provide a selected timing of changing the operational state of the relays, wherein the selected timing is a function of at least one of: the operational characteristics of one or more of the relays, and the power cycle time in the system.

[0043] In another embodiment, a controller and method disclosed herein provide selected timing of control signals to multiple relays such that the order of opening and closing relays in a sequence as a function of switch transfer time and system power cycle time.

[0044] According to one embodiment disclosed herein, said selected timing comprises a set time to wait between in a sequence of turning relays on or off. In one example, the set time to wait is based on the 'time to actuate' or transfer time of a relay, and the system power cycle time.

[0045] The disclosed embodiments provide a controller and method for selected timing of control signals to multiple relays in a system such that each relay can take turns absorbing electromechanical energy including destructive arcing (electrical spark) energy released when a relay is closed or released first. In a system including N relays (where Nis an integer greater than 1), a relay that would normally absorb more of electromechanical energy from turning on or off first, will only absorb such energy about 1/N number of times according to an embodiment disclosed herein. For example, in a system including two relays (N=2), a relay that would normally absorb more electromechanical energy from turning on or off first, will only absorb such energy about half the number of times.

[0046] Examples embodiments are disclosed herein in conjunction with electric vehicle supply equipment (EVSE) for an example context, however the disclosed method and system herein can be implemented in different electrical systems. In an EVSE including multiple relays, if one of two or more relays is switched on or switched off more frequently than another relay, such a relay may fail prematurely or go into a reduced/degraded state of operation degrading system performance. FIG. **1** depicts an exemplary system **100** for controlling power between a utility **102** and an electric vehicle (EV) **104**. The system may include an EVSE **106** to charge the EV **104** with power provided by the utility **102**. While this system is described with reference to an EVSE, it may be applied to other electrical systems, such as a wall socket in a building. The EVSE **106** may include a current sensing transformer **108**. One or more utility lines **114**, **116**, depicted as solid lines and dashed lines in the EVSE **106**, may connect to the transformer **108**.

[0047] A microcontroller **110** may be in communication with the transformer. The microcontroller **110** may determine if a fault event occurs. In some embodiments, the fault event may be a leakage current fault, temperature fault, or other faults. The vehicle or user may also command the EVSE to end the charge session for any reason. The microcontroller **110** may send a signal to two or more relays **112** and/or to the transformer **108** to control power between the EVSE **106** and/or the EV **104** and the utility **102**. While a microcontroller **110** is depicted in the system **100**, one or all of its functions may be replaced by analog and logic circuitry in some embodiments as disclosed herein.

Likewise, additional microcontrollers may be used to accomplish different functions.

[0048] The microcontroller **110** may further be configured to selectively change the operational state of one or more of the relays **112** on/off, to reduce early degradation of one or more of the relays in relation to other relays in the system, according to the embodiments disclosed herein.

[0049] The two or more relays **112** may each include one or more contacts, such as a first contact and a second contact. In some embodiment, there may be more than two contacts. In some embodiments, the system and method disclosed herein may be applied to multiple relays.

[0050] The microcontroller **110** may send a relay signal to the two or more relays **112** to each switch on and/or switch off. While a microcontroller **110** is depicted in the system **100**, one or all of its functions may be replaced by analog and logic circuitry in some embodiments as disclosed herein. In some embodiments, the microcontroller **110** may continuously check the status of the two or more relays **112** to detect system or relay conditions. In some embodiments, the microcontroller **110** checks the status of the two or more relays **112** at a set interval to detect any fault or degradation conditions. In some embodiments, the microcontroller **110** may only check the status of the two or more relays **112** when the relay is expected to change state, such as when a new relay signal is sent to the relay to switch from on to off. In some embodiments, the microcontroller **110** may check the two or more relays **112** continuously.

[0051] FIG. **2** depicts a cross-sectional side view and schematic of an embodiment of a system **200** including an EVSE **10**, power outlet, and protective enclosure, in which embodiments of the system and method disclosed herein may be implemented. In embodiments, the EVSE **10** includes a cord **14** and a case **16** and is shown plugged into a power outlet **54** of a power source **50** and within a protective cover **52**. The EVSE **10** shown includes a control system **20** that is connected to a pilot line, which in turn may be connected to an electric vehicle via a connector (not shown). The control system **20** is further connected to a set of contactors, relays, or electrical switches **26** and **28**, which function to control the flow of power from the power source **50** to the vehicle. In one embodiment, the control system **20** is configured to selectively change the operational state of one or more of the electrical switches such as relays, to reduce early degradation of one or more of the relays in relation to other relays.

[0052] In one embodiment, the control system **20** operates to open or close the relays **26** and/or **28** as directed by the status of the pilot signal on the pilot line, including as directed by the vehicle or when the pilot line is disconnected from the vehicle. The control system **20** can include a relay controller **22** and a relay monitor **24**. The relay controller **22** controls the operation of the relays **26** and/or **28** to selectively change the operational state of one or more of the relays, to reduce early degradation of one or more of the relays in relation to other relays, according to embodiments disclosed herein. In one embodiment, the relay monitor **24** checks that the operation or position of relays **26** and/or **28** matches their commanded position or positions. In the event the relay monitor **24** detects that either relay **26** and/or **28** are not functioning as commanded, the relay monitor **24** will indicate an error has occurred in the operation of the EVSE **10**. Such indication may be by illuminating a warning light (not shown).

[0053] FIG. **3** illustrates one embodiment of an EVSE system **300** that uses AC utility power to charge electric vehicles. The system is operable to plug into an AC source that may be 120 VAC-60 Hz, 250 VAC-60 Hz (split phase) or 230 VAC 50 Hz (80 VAC to 264 VAC) via a standard NEMA or CEE7/7 plug from a standard household utility socket. The AC power is routed to a GFI Monitor **302** that is a GFI/RCD (Ground Fault Interrupter/Residual Current Device current sensor) through relays **304** for presentation to an EV charge cable **306**. The relays **304** are normally open (N. O.) when de-energized, so logic power must be present in order to initiate and maintain the relay-closed condition. The relay or relays **304** open/close operation is driven by the relay control driver **307**. In one embodiment, the relay control driver **307** may be configured to selectively change the operational state of one or more of the relays **304** on/off, to reduce early degradation of one or more of the relays in relation to other relays in the system, according to the embodiments disclosed herein.

[0054] In one embodiment, the GFI monitor **302**, relay control driver and fault latch controller **307** collectively provide a robust hardware safety system. A controller **308** receives line voltage signals from an AC voltage monitor **310** through an analog multiplexor **312**, with the AC voltage monitor **310** monitoring the voltage on Line 1 and Line 2 and across the relays **304** for communication to the controller **308**. The controller **308** includes a microprocessor and control monitoring electronics, with logic power being supplied by a power supply **309** that may be a flyback transformer-based power supply to allow for use of the EVSE system **300** in different power environments. The prime function of the controller **308** is to use the inputs from the vehicle connector and utility to allow or disallow the relays to open and close. It allows closure when conditions are normal and ensures the relays open in any safety-required fault or disconnection event. It obtains its operating power from the utility at the input of the EVSE system **300**.

[0055] A charge coupler **314** such as an SAE-J1772 or IEC-62196 Type II, Mode 2 compliant connector is in communication with the EV charge cable **306** to feed the AC power to an EV (not shown) that may be coupled to the charge coupler. The EV (now shown) may contain an onboard charger that then converts the AC power to DC power to charge the vehicle batteries. For example, in preparation to operate the EVSE system **300**, the connector is attached by the user to the vehicle receptacle for charging sessions. The vehicle is the primary system component per SAE-J1772/IEC62196 that communicates charging status and completion to the user, however the controller **308** may be designed to provide a primary pilot signal through the pilot driver and monitor **315**, with the pilot signal established between the EVSE and the vehicle per SAE-J1772 prior to closing the relays **304**. The pilot signal is passed through the charging cable **306** to the vehicle and may have a peak amplitude of +/−3 V and a PWM (Pulse Width Modulation). Per SAE-J1772, the duty cycle of the pilot PWM signal is used by the EVSE system **300** to communicate the maximum power amperage limit that the EVSE system **300** may supply to the vehicle. The pilot signal voltage amplitude and modulation characteristics are used to indicate a proper connection, charging requirements, and default status between the vehicle and the EVSE system **300**.

[0056] Also included in the EVSE system **300** may be a plug blade temperature thermistor **316** positioned and potted in thermal communication with the plug blades **318** of a receptacle plug blade assembly **320**, with the plug blade temperature thermistor **316** in communication with the controller **308**. A reference temperature thermistor **322** is positioned remotely from the plug blade temperature thermistor **316** to enable measurement of differential temperatures at such locations and is also in communication with the controller **308**. With the inclusion of the plug blade temperature thermistor **316** and reference temperature thermistor **322**, means are provided for avoiding excessive heat that may cause damage to the receptacle plug blade assembly by using either an absolute temperature as measured at the receptacle plug blade assembly or a temperature differential calculated using measurements taken by the plug blade temperature thermistor and reference temperature thermistor to enable intelligent control of the EV charging current through modulation of the pilot signal sent by the controller **308**.

[0057] The EVSE system **300** may have a user interface **324** that may include an LED light or lights and one or more switch inputs that are in communication with the controller **308**. In one embodiment, the LED light is one green LED. When the EVSE system **300** is not plugged into a wall outlet, the LED may be off. When the EVSE system **300** is plugged into a wall outlet and is not charging (stand-by state) the LED may be solid on. During the charging state, the LED will display a smooth transition from fully on to barely visible. The trouble codes may be depicted through various flash rates of the LED that will be distinctly different from the other states. Because the EVSE system **300** is able to communicate through the charge coupler **314**, in one embodiment, the charge coupler **314** may be connected to a personal computer to configure the EVSE system **300** for a maximum current rating for a particular region. Software embedded or otherwise stored and used by the controller **308** may be updated through the charge coupler **314** to make upgrades in the field very easy. Also included in the EVSE system **300** is a missing ground detector **326** in electrical communication with both line 1 and line 2 to provide missing ground current and missing ground voltage signals to the controller **308**. As shown more particularly, a proximity monitor **328** is in electrical communication with the charge coupler **314** through the EV charge cable **306** to enable EVSE programming. A DC bias circuit is provided through bias resisters Rx **330** and RY **332** (preferably 300 k ohms, each) in electrical communication with Line 1 and Line 2, respectively, to enable bipolar output impedance and welded contact tests.

[0058] In one embodiment, a controller and method disclosed herein provide selected timing of control signals to multiple relays such that relays are turned on/off in an alternating sequence. FIG. **4** is a block diagram illustrating an electrical system **400** for alternating relays to extend relay life, according to one embodiment. The system **400** may include a first powerline **402** (Line 1 Power) connecting a first relay **406** (RELAY 1) to an electrical power source **401**, and a second powerline **404** (Line 2 Power) connecting a second relay **408** to the power source **401**. The first relay **406** may include a first coil **403** connected to a first relay control **414** (Control Relay 1) and a first coil energizer power source **410** (e.g., 15V power source).

[0059] Activating the first coil by the first relay control **414** may close the contacts **407** of the first relay **406** and provide power to a load **422** via an electrical power line **418** (Relay L1 Line) when both the relays **406** and **408** are turned on. The second relay **408** may include a second coil **405** connected to a second relay control **416** (Control Relay 2) and a second coil energizer power source **412** (e.g., 15V power source). Activating the second coil **405** by the second relay control **416** may close the contacts **409** of the second relay **408** and provide power to the load **422** via an electrical power line **420** (Relay L2 Line) when both the relays **406** and **408** are turned on. The load **422** is powered by the power source **401** when both the relays **406** and **408** are turned on (i.e., powered on, closed, make contact).

[0060] In one embodiment, the relay controller **414** and the relay controller **416** are configured to provide selected timing of control signals to energize (and de-energize) the relay coils **403**, **405**, such that relays **406** and **408** are turned on/off in an alternating sequence, such that same relay is not always first to turn on or first to turn off. In one embodiment, the controllers **414** and **416** are in communication for synchronizing sending control signals to the relays. In another embodiment the controllers **414** and **416** may be implemented in one microcontroller **110** (FIG. **1**) for controlling multiple relays.

[0061] FIG. **5** shows a cartesian representation **500** of electrical signals in an example operation of the system **400** of FIG. **4**, according to one embodiment disclosed herein. In the representation **500**, the horizontal axis represents time, and the vertical axis represents signal amplitude. The graph **506** indicates the control signal to the first relay **406** (RELAY 1) from the controller **414**. At a first time **510**, the controllers **414** and **416** signal the coil energizers **410**, **412**, respectively, to maintain the coils **403** and **405** de-energized, whereby both relays **406**, **408** are turned off.

[0062] At a second time **512**, the control signal **506** from the first relay controller **414** to the coil energizer **410** goes low to turn on the first relay **406**, whereby the coil energizer **410** begins to energize the first coil **403** and after a transfer time a magnetic field build up causes the contacts **407** to make contact/close (relay **406** is turned on) at a third time **514**. In one example, it takes a transfer time of about 9 ms from the second time **512** when the controller **414** signals the coil energizer **410** to turn on the coil **403**, for the contacts **407** to close and the relay L1 contact line **418** to be energized.

[0063] Between the second time **512** and a third time **514**, the second relay controller **416** is turned on whereby a control signal (not shown) to the coil energizer **412** causes the coil energizer **412** to begin energizing the second coil **405** and after a transfer time a magnetic field build up in the second coil **405** causes the contacts **409** of the second relay **408** to make contact/close (relay **408** is turned on) at the fourth time **516**. At this time (e.g., about 5.5 ms after the third time **514**), with both the first and second relays **406** and **408** turned on (i.e., contacts closed), current signal **508** flows between the power source and the load **422** through the relays **406** and **408**. Current signal **508** does not begin to flow until both relays **406** and **408** are on (i.e., closed, engaged). In this example, at the fourth time **516**, the electrical signal **504** on the Relay L1 Line contact **418** is 180 degrees out of phase with the electrical signal **502** on the Relay L2 Line contact **420**, to provide 240V split phase power.

[0064] In the example operation shown in FIG. **5** for the system **400** in FIG. **4**, the first relay **406** is turned on first and then the second relay **408** is turned on, wherein the second relay **408** is exposed to more electromechanical stress as compared to the first relay **406**. The same process as shown in FIG. **5** for turning each of the relays on, occurs in reverse order when each of the relays are turned off.

[0065] Graphs **502** and **504** show signal bounce at relay contacts. The signal **504** for Relay L1 Line and the signal **502** for Relay L2 Line are in phase, which means that only one of the relay contacts has transferred (i.e., closed).

[0066] At the third time **514**, about 9 ms after the second time **512**, the first relay contacts engage and the Relay L1 contact line is energized. Current **508** does not yet begin to flow at the third time **514**. When only the first relay **406** is on, the voltage at the other side of the load **422** follows at the same potential, and current does not flow from the power source **401** through the load **422**.

[0067] The electrical system including the relays, has an associated power cycle time period which is the time between one power on, to the next, or from one power off to the next. In one example, power cycle time means 50 Hz or 60 Hz utility power supply grids. It can mean other periods of time for one complete cycle of system operation. At 60 Hz, the time period for one power cycle is about 16.7 milliseconds (ms) or about 0.0167 seconds from start to finish. For 50 Hz, the power cycle time period is about 20 ms which for 120 Volts AC means at time 0 ms at the start of a power cycle. voltage signal is 0V (i.e., zero crossing positive slope). At 5 ms, the voltage signal has risen to about 180 V (i.e., positive or maximum peak). At 10 ms, the voltage signal has returned back to 0V (i.e., zero crossing negative slope). At 15 ms, the voltage signal is down at −180V (i.e., negative minimum peak), and then at 20 ms, the voltage signal returns back to zero which is the start of a new power cycle.

[0068] According to one embodiment disclosed herein, said selected timing comprises a set time to wait in a sequence of turning relays on or off using actuation and de-actuation control signals, respectively. In one example, the set time to wait is based on the ‘time to actuate’ or transfer time of a relay, and the system power cycle time. In one example embodiment, in relation to the system power cycle time, if (a) the relay transfer time is 25 ms from the actuation signal to turn on the relay and the time relay contacts are closed and the relay is on, and (b) it is desired to turn on the relay during the positive slope of the voltage signal zero crossing, then once that zero crossing signal is detected (e.g., for a 50 Hz system) a timer is set to wait for 15 ms before actuating the next relay. Five milliseconds later a voltage signal zero crossing occurs and after the remaining transfer time of 20 ms is elapsed, the relay contacts would complete that connection, doing so at that next zero crossing.

[0069] Another example is with a relay that has a transfer time of only 5 ms. A common signal to sense is when the incoming power electrical signal crosses the zero-voltage point. For a 50 Hz system, once the zero crossing is detected, it will be another 20 ms before the next zero crossing. At that time, sending an actuation signal to turn on the relay (i.e., close relay contacts), the relay would be actuated 15 ms after detection of a zero crossing. Then 5 ms later the contacts will have transferred and zero crossing is achieved.

[0070] With temperature variation and the effects of aging, it is possible for a relay transfer time to change. According to one embodiment disclosed herein, when using two or more relays in a system, one relay is completely closed (transfer time including any bouncing of the contacts) before the other relay starts closing. This is based on pertinent relay specifications and adding a time period safety factor in determining said set time to wait.

[0071] In one example application, for reasons of safety when using alternating current (AC) utility power in an EVSE to charge an electric vehicle, it is required to switch on both lines **402** and **404** via the relays **406** and **408**, respectively. The relays used for electric vehicle charging are rated for such an application and at full power transfer may last about 10,000 on/off cycles. Separate relays are needed for safety reasons to apply power from a source utility having 120V, 240V, or other voltage supply. When turning two or more relays on, the priority is to turn both relays on at the same time. When a system sends a signal to turn both relays on and/or off at the very same time, one of the relays will consistently turn on and/or turn off faster than the other relay or relays. A relay that turns off faster generally consistently turns off faster. The first relay to turn off or release is the relay that gets the brunt of the force on the release cycle.

[0072] The disclosed system and method herein intentionally alternates between turning on relays so that each relay can take turns absorbing the destructive arc energy released when the relay is closed or released first. The relay that would normally absorb more of this destructive energy from turning on or off first will only absorb this energy about half the time in the disclosed system and method.

[0073] The load that the relay contacts are powering is different than what the life testing load is. Consequently, a relay rated for 10,000 cycles will translate into 5,000 through 8,000 cycles for a typical system using two relays where one of the relays consistently turns on and/or off before the other relay. The faster relay may not have a longer cycle life. Therefore, a system could last as few as 5,000 cycles or 8,000 cycles even though the individual relays are rated for 10,000 cycles each. By contrast, a system with two relays and controllers implementing embodiments of the system and method disclosed herein may be able to be extended to 10,000 or even 12,000 relay on/off cycles by alternating the destructive energy absorbed by any one relay in the system.

[0074] Referring to FIGS. **6**A-**6**E, embodiments of a method implemented in a system for relay operation are disclosed. The method of turning multiple relays on/off disclosed herein may be implemented in a controller such as a digital controller, analog controller, microcontroller, microprocessor, etc. A memory device may be utilized to store relay information such as the on/off state of a relay, selected timing sequence for turning relays on/off, etc.

[0075] According to one embodiment, an example electrical system includes N relays such as Relay 1, Relay 2, . . . , Relay N. The relays are turned on/off in alternating sequence by the controller control signals after a set wait time for each relay, based on a sequence of N control states (e.g., stored in a memory device). Each control state specifies which relay is first to be turned on or first to be turned off, during a system power cycle. At the next power cycle, the next relay in the sequence is first to be turned on or off.

[0076] For example, when N=4, using a control state counter C, in control state C=1, in a power cycle upon receiving a power on signal to power the load from the power supply, Relay 1 is turned on first, and then subsequent relays are turned on in sequence after a set wait time has passed for each (i.e., after a set wait time Relay 2 is turned on second, after a set wait time Relay 3 is turned on third, after a set wait time Relay 4 is turned on fourth). Upon receiving a power off signal, Relay 1 is turned off first, and then subsequent relays are turned off in sequence after a set wait time has passed for each (i.e., after a set wait time Relay 2 is turned off second, after a set wait time Relay 3 is turned off third, after a set wait time Relay 4 is turned off fourth). The control state counter C is incremented by one.

[0077] For the next power cycle, in control state C=2, upon receiving a power on signal to power the load from the power supply, Relay 2 is turned on first, and then subsequent relays are turned on in sequence after a set wait time has passed for each (i.e., after a set wait time Relay 3 is turned on second, after a set wait time Relay 4 is turned on third, after a set wait time Relay 1 is turned on fourth). Upon receiving a power off signal Relay 2 is turned off first, and then subsequent relays are turned off in sequence after a set wait time has passed for each (i.e., after a set wait time Relay

3 is turned off second, after a set wait time Relay 4 is turned off third, after a set wait time Relay 1 is turned off fourth). The control state counter is incremented by one.

[0078] For the next power cycle, in control state C=3, upon receiving a power on signal to power the load from the power supply, Relay 3 is turned on first, and then subsequent relays are turned on in sequence after a set wait time has passed for each (i.e., after a set wait time Relay 4 is turned on second, after a set wait time Relay 1 is turned on third, after a set wait time Relay 2 is turned on fourth). Upon receiving a power off signal Relay 3 is turned off first, and then subsequent relays are turned off in sequence after a set wait time has passed for each (i.e., after a set wait time Relay 4 is turned off second, after a set wait time Relay 1 is turned off third, after a set wait time Relay 2 is turned off fourth). The control state counter is incremented by one.

[0079] For the next power cycle, in control state C=4, upon receiving a power on signal to power the load from the power supply, Relay 4 is turned on first, and then subsequent relays are turned on in sequence after a set wait time has passed for each (i.e., after a set wait time Relay 1 is turned on second, after a set wait time Relay 2 is turned on third, after a set wait time Relay 3 is turned on fourth). Upon receiving a power off signal Relay 4 is turned off first, and then subsequent relays are turned off in sequence after a set wait time has passed for each (i.e., after a set wait time Relay 1 is turned off second, after a set wait time Relay 2 is turned off third, after a set wait time Relay 3 is turned off fourth). When C=N, the control state counter is reset (i.e., C=1), and for the next power cycle the process repeats such that in control state C=1, upon receiving a power on signal, Relay 1 is turned on first, and then subsequent relays are turned on in sequence after a set wait time has passed for each (i.e., after a set wait time Relay 2 is turned on second, after a set wait time Relay 3 is turned on third, after a set wait time Relay 4 is turned on fourth). Upon receiving a power off signal, Relay 1 is turned off first, and then subsequent relays are turned off in sequence after a set wait time has passed for each (i.e., after a set wait time Relay 2 is turned off second, after a set wait time Relay 3 is turned off third, after a set wait time Relay 4 is turned off fourth). The control state counter C is incremented by one. And so on.

[0080] The state counter C cycles through counts 1, 2, . . . , N, 1, 2, . . . , N, 1, 2, . . . , N and so on. As such, for a power cycle in a control state C, upon receiving a power on signal, Relay C is turned on first, and then subsequent relays are turned on in sequence after a set wait time has passed for each, as described by the example above. Next, in control state C, upon receiving a power off signal, Relay C is turned off first, and then subsequent relays are turned off in sequence after a set wait time has passed for each, as described by the example above. When C=N, the control state counter C is reset (i.e., C=1), and for the next power cycle the process repeats.

[0081] FIG. **6**A depicts a flow chart of a method embodiment **600** of turning two or more relays on/off in an electrical system. The method **600** may include storing, by a processor (e.g., controller, electronic control), a first state based on an order of two or more relays to be switched on (i.e., turned on, engaged) (step **602**). The method **600** may then include sending, by the processor, one or more first control signals to switch on a relay of two or more relays based on the stored first state (step **604**). The method **600** may then include waiting, by the processor, for a selected time after sending each first signal of the one or more first signals (step **606**). The method **600** may then include updating, by the processor, the first state based on the order the one or more first signals were sent (step **608**).

[0082] FIG. **6**B depicts a flow chart of a method embodiment **601** of switching off two or more relays. The method **601** may include storing, by a processor, a second state based on an order of two or more relays to be switched off (step **610**). The method **601** may then include sending, by the processor, one or more second signals to switch off (i.e., turn off) a relay of two or more relays based on the stored second state (step **612**). The method **601** may then include waiting, by the processor, for a set time after sending each second signal of the one or more second signals (step **614**). The method **601** may then include updating, by the processor, the second state based on the order the one or more second signals were sent (step **616**). In some embodiments, the relays may be turned off in any order, simultaneously, or near simultaneously. Turning the relays off may not subject the relay to the stresses experienced while turning the relays on and may not otherwise shorten the life of the relays and the system using the relays.

[0083] As an example, Relay A may have a life cycle of 5,000 cycles and Relay B may have a life cycle of 8,000 cycles. Relay A is switched on first and a few milliseconds later Relay B is switched on. Next time the relays need to be turned on, the system switches on (turns on) Relay B first, waits a few milliseconds and then switches on Relay A. The same alternating process is used to switch each relay off. By using the disclosed system and method, it may now take 10,000 cycles for Relay A to reach the end of its useful life. That is, it takes twice as long for Relay A (2× the original life cycle of 5,000) or 10,000 cycles to reach the system's fail point.

[0084] For half of the cycles, one relay is switching into a Very Low/No Load which can slow down the amount of contact degradation. The disclosed system and method may be implemented in an existing charging system having an electrical control having two or more relays. In some embodiments, no additional hardware is needed.

[0085] A system that uses two relays for the transfer of AC Power to a load may have its usable life expectancy approximately doubled. In some embodiments, the usable life may be even more than two times the life of the relay that would have failed first.

[0086] The disclosed system and method may be applied across multiple industries and uses where two or more relays are switched on at the same or similar time. Other uses may include, but are not limited to, building lighting, motor controls, a three-phase industrial system with three relays, and a three-phase industrial system with four relays where a neutral is switched, also transistor/SCR/TRIACs/IBGTs/and the like.

[0087] FIG. **6**C depicts a flow chart of a method embodiment **618** of switching on two relays. The method **618** may include storing a state, where the state comprises an order of two relays to be switched on (step **620**). The method **618** may then include sending a first signal, based on the state, to switch on a first relay of two relays (step **622**). The method **618** may then include waiting for a set time after sending the first signal (step **624**). The method **618** may then include sending a second signal to switch on a second relay of the two relays (step **626**). The method **618** may then include updating the state based on the order the first signal and the second signal were sent (step **628**). The method **618** may then include sending the second signal, based on the state, to switch on the second relay of two relays (step **630**). The method **618** may then include waiting for a set time after sending the second signal (step **632**). The method **618** may then include sending the first signal to switch on the first relay of the two relays (step **634**). The method **618** may then include updating the state based on the order the first signal and the second signal were sent (step **636**). The method **618** may then repeat with step **622** such that the system alternates between turning the first relay on first and the second relay on first. While the method **618** is disclosed for two relays, the method may be used with any number of relays such that the order of the relays being turned on first is alternated.

[0088] FIG. **6**D depicts a flow chart of a method embodiment **600**D of switching on three relays. The method **600**D may include storing a first state of N states where Nis a number of relays and where each state comprises an order of relays to be switched on (step **602**D). In the first state, the method **600**D may include sending first through third signals to turn on first through third relays (steps **604**D-**612**D). In the first state, the method **600**D may then include sending fourth through sixth signals to turn off the first through third relays (steps **614**D-**622**D). The method **600**D then updates the stored state to a second state (step **624**D). The first relay may be relay A. The second relay may be relay B. The third relay may be relay C. The order of turning the relays on and off in the first state may be A, B, C and A, B, C. The order of turning the relays on and off in the second state may be B, C, A and B, C, A. The order of turning the relays on and off in the third state may be C, A, B and C, A, B. Other orders of turning the relays on and off for each state are possible and contemplated. The method **600**D is shown with reference characters A and B connecting the flowchart steps.

[0089] The method **600**D may include storing a first state of n states, where n is a number of relays, where each state comprises an order of relays to be switched on (step **602**D). The method **600**D may then include sending a first signal, based on the first state, to switch on a first relay (step **604**D). The method **600**D may then include waiting for a set time after sending the first signal (step **606**D). The method **600**D may then include sending a second signal, based on the first state, to switch on a second relay (step **608**D). The method **600**D may then include waiting for the set time after sending the second signal (step **610**D). The method **600**D may then include sending a third signal based on the first state, to switch on a third relay (step **612**D). The method **600**D may then include sending a fourth signal, based on the first state, to switch off the first relay (step **614**D). The method **600**D may then include waiting for a set time after sending the fourth signal (step **616**D). The method **600**D may then include sending a fifth signal, based on the first state, to switch off the second relay (step **618**D). The method **600**D may then include waiting for the set time after sending the fifth signal (step **620**D). The method **600**D may then include sending a sixth signal, based on the first state, to switch off the third relay (step **622**D). The method **600**D may then include updating the stored state to a second state (step **624**D). The method **600**D may then include sending the first signal, based on the second state, to switch on the second relay (step **626**D). The method **600**D may then include waiting for the set time after sending the first signal (step **628**D). The method **600**D may then include sending the second signal, based on the second state, to switch on the third relay (step **630**D). The method **600**D may then include waiting for the set time after sending the second signal (step **632**D). The method **600**D may then include sending the third signal, based on the second state, to switch on the first relay (step **634**D). The method **600**D may then include sending the fourth signal, based on the second state, to switch off the second relay (step **636**D). The method **600**D may then include waiting for a set time after sending the fourth signal (step **638**D). The method **600**D may then include sending the fifth signal, based on the second state, to switch off the third relay (step **640**D). The method **600**D may then include waiting for the set time after sending the fifth signal (step **642**D). The method **600**D may then include sending the sixth signal, based on the second state, to switch off the first relay (step **644**D). The method **600**D may then include updating the stored state to a third state (step **646**D).

[0090] The method **600**D may then include sending the first signal, based on the third state, to switch on the third relay (step **648**D). The method **600**D may then include waiting for the set time after sending the first signal (step **650**D). The method **600**D may then include sending the second signal, based on the third state, to switch on the first relay (step **652**D). The method **600**D may then include waiting for the set time after sending the second signal (step **654**D). The method **600**D may then include sending the third signal, based on the third state, to switch on the second relay (step **656**D). The method **600**D may then include sending the fourth signal, based on the third state, to switch off the third relay (step **658**D). The method **600**D may then include waiting for a set time after sending the fourth signal (step **660**D). The method **600**D may then include sending the fifth signal, based on the third state, to switch off the first relay (step **662**D). The method **600**D may then include waiting for the set time after sending the fifth signal (step **664**D). The method **600**D may then include sending the sixth signal, based on the third state, to switch off the second relay (step **666**D). The method **600**D may then include updating the stored state to the first state (step **668**D).

[0091] FIG. **6**E depicts a flow chart of a method embodiment **600**E of switching on four relays. The first relay may be relay A. The second relay may be relay B. The third relay may be relay C. The fourth relay may be relay D. The order of turning the relays on and off in the first state may be A, B, C, D and A, B, C, D. The order of turning the relays on and off in the second state may be B, C, D, A and B, C, D, A. The order of turning the relays on and off in the third state may be C, D, A, B and C, D, A, B. The order of turning the relays on and off in the fourth state may be D, A, B, C, and D, A, B, C. Other orders of turning the relays on and off for each state are possible and contemplated. The method **600**E is shown with reference characters A, B, D, D, E, F, and G connecting the flowchart steps.

[0092] The method **600**E may include storing a first state of n states, where n is a number of relays, where each state comprises an order of relays to be switched on (step **601**E). The method **600**E may then include sending a first signal, based on the first state, to switch on a first relay (step **602**E). The method **600**E may then include waiting for a set time after sending the first signal (step **604**E). The method **600**E may then include sending a second signal, based on the first state, to switch on a second relay (step **608**E). The method **600**E may then include waiting for the set time after sending the second signal (step **610**E). The method **600**E may then include sending a third signal, based on the first state, to switch on a third relay (step **612**E). The method **600**E may then include waiting for the set time after sending the third signal (step **614**E). The method **600**E may then include sending a fourth signal, based on the first state, to switch on a fourth relay (step **616**E). The method **600**E may then include sending a fifth signal, based on the first state, to switch off the first relay (step **618**E). The method **600**E may then include waiting for the set time after sending the fifth signal (step **620**E). The method **600**E may then include sending a sixth signal, based on the first state, to switch off the second relay (step **622**E). The method **600**E may then include waiting for the set time after sending the sixth signal (step **624**E). The method **600**E may then include sending a seventh signal, based on the first state, to switch off the third relay (step **626**E). The method **600**E may then include waiting for the set time after sending the seventh signal (step **628**E). The method **600**E may then include sending an eighth signal, based on the first state, to switch off the fourth relay (step **630**E). The method **600**E may then include updating the stored state to a second state (step **632**E). The method **600**E may then include sending the first signal, based on the second state, to switch on the second relay (step **634**E). The method **600**E may then include waiting for the set time after sending the first signal (step **636**E). The method **600**E may then include sending the second signal, based on the second state, to switch on the third relay (step **638**E). The method **600**E may then include waiting for the set time after sending the second signal (step **640**E). The method **600**E may then include sending the third signal, based on the second state, to switch on the fourth relay (step **644**E). The method **600**E may then include waiting for the set time after sending the third signal (step **646**E). The method **600**E may then include sending the fourth signal, based on the second state, to switch on the first relay (step **648**E). The method **600**E may then include sending the fifth signal, based on the second state, to switch off the second relay (step **650**E). The method **600**E may then include waiting for the set time after sending the fifth signal (step **652**E). The method **600**E may then include sending the sixth signal, based on the second state, to switch off the third relay (step **654**E). The method **600**E may then include waiting for the set time after sending the sixth signal (step **656**E). The method **600**E may then include sending the seventh signal, based on the second state, to switch off the fourth relay (step **658**E). The method **600**E may then include waiting for the set time after sending the seventh signal (step **660**E). The method **600**E may then include sending the eighth signal, based on the second state, to switch off the first relay (step **662**E). The method **600**E may then include updating the stored state to a third state (**664**E). The method **600**E may then include sending the first signal, based on the third state, to switch on the third relay (step **666**E). The method **600**E may then include waiting for the set time after sending the first signal (step **668**E). The method **600**E may then include sending the second signal, based on the third state, to switch on the fourth relay (step **670**E). The method **600**E may then include waiting for the set time after sending the second signal (step **672**E). The method **600**E may then include sending the third signal, based on the third state, to switch on the first relay (step **674**E). The method **600**E may then include waiting for the set time after sending the third signal (step **676**E). The method **600**E may then include sending the fourth signal, based on the third state, to switch on the second relay (step **678**E). The method **600**E may then include sending the fifth signal, based on the third state, to switch off the third relay (step **680**E). The method **600**E may then include waiting for the set time after sending the fifth signal (step **682**E). The method **600**E may then include sending the sixth signal, based on the third state, to switch off the fourth relay (**684**E). The method **600**E may then include waiting for the set time after sending the sixth signal (step **686**E). The method **600**E may then include sending the seventh signal, based on the third state, to switch off the first relay (step **688**E).

[0093] The method **600**E may then include waiting for the set time after sending the seventh signal (step **690**E). The method **600**E may then include sending the eighth signal, based on the third state, to switch off the second relay (step **692**E). The method **600**E may then include updating the stored state to a fourth state (step **694**E). The method **600**E may then include sending the first signal, based on the fourth state, to switch on the fourth relay (step **696**E). The method **600**E may then include waiting for the set time after sending the first signal (step **698**E). The method **600**E may then include sending the second signal, based on the fourth state, to switch on the first relay (step **6001**). The method **600**E may then include waiting for the set time after sending the second signal (step **6002**). The method **600**E may then include sending the third signal, based on the fourth state, to switch on the second relay (step **6003**). The method **600**E may then include waiting for the set time after sending the third signal (step **6004**). The method **600**E may then include sending the fourth signal, based on the fourth state, to switch on the third relay (step **6005**). The method **600**E may then include sending the fifth signal, based on the fourth state, to switch off the fourth relay (step **6006**). The method **600**E may then include waiting for the set time after sending the fifth signal (step **6007**). The method **600**E may then include sending the sixth signal, based on the fourth state, to switch off the first relay (step **6008**). The method **600**E may then include waiting for the set time after sending the sixth signal (step **6009**). The method **600**E may then include sending the seventh signal, based on the fourth state, to switch off the second relay (step **6010**). The method **600**E may then include waiting for the set time after sending the seventh signal (step **6011**). The method **600**E may then include sending the eighth signal, based on the fourth state, to switch off the third relay (step **6012**). The method **600**E may then include updating the stored state to the first state (step **6013**).

[0094] Embodiments disclosed herein comprise systems, devices, and methods including: an electronic device configured to store the last known operational state of electrical relays in an electrical system, wherein the electronic device is in communication with two or more relays, and the electronic device is configured to: store a first state based on an order of two or more relays to be turned on; send one or more first signals to switch on a relay of two or more relays based on the stored first state; wait for a set time after sending each first signal of the one or more first signals; and update the first state based on the number of relays in the system and the order of signals that were sent. According to one embodiment, the actuation controls (energizing of the relay coils) is performed such that the actuation of the relays being alternated would be of benefit.

[0095] FIG. **7** illustrates an example of a top-level functional block diagram of a computing device embodiment **700**. The example operating environment is shown as a computing device **720** comprising a processor **724**, such as a central processing unit (CPU), addressable memory **727**, an external device interface **726**, e.g., an optional universal serial bus port and related processing, and/or an Ethernet port and related processing, and an optional user interface **729**, e.g., an array of status lights and one or more toggle switches, and/or a display, and/or a keyboard and/or a pointer-mouse system and/or a touch screen. Optionally, the addressable memory may include any type of computer-readable media that can store data accessible by the computing device **720**, such as magnetic hard and floppy disk drives, optical disk drives, magnetic cassettes, tape drives, flash memory cards, digital video disks (DVDs), Bernoulli cartridges, RAMs, ROMs, smart cards, etc. Indeed, any medium for storing or transmitting computer-readable instructions and data may be employed, including a connection port to or node on a network, such as a LAN, WAN, or the Internet. These elements may be in communication with one another via a data bus **728**. In some embodiments, via an operating system **725** such as one supporting a web browser **723** and applications **722**, the processor **724** may be configured to execute steps of a process establishing a communication channel and processing according to the embodiments described above.

[0096] The disclosed method and system allow for the detection of a status of each relay, and indicate whether the relay is operating correctly, when there is a fault condition, such as when relay contacts are degraded or welded together. In one example, reflector may be added onto one of the relay contacts to reflect a signal from an emitter. A detector may receive the reflected signal to determine the status of the relay.

[0097] FIG. **8** is a high-level block diagram **800** showing a computing system comprising a computer system useful for implementing an embodiment of the system and process, disclosed herein. Embodiments of the system may be implemented in different computing environments. The computer system includes one or more processors **802**, and can further include an electronic display device **804** (e.g., for displaying graphics, text, and other data), a main memory **806** (e.g., random access memory (RAM)), storage device **808**, a removable storage device **810** (e.g., removable storage drive, a removable memory module, a magnetic tape drive, an optical disk drive, a computer readable medium having stored therein computer software and/or data), user interface device **811** (e.g., keyboard, touch screen, keypad, pointing device), and a communication interface **812** (e.g., modem, a network interface (such as an Ethernet card), a communications port, or a PCMCIA slot and card). The communication interface **812** allows software and data to be transferred between the computer system and external devices. The system further includes a communications infrastructure **814** (e.g., a communications bus, cross-over bar, or network) to which the aforementioned devices/modules are connected as shown.

[0098] Information transferred via communications interface **814** may be in the form of signals such as electronic, electromagnetic, optical, or other signals capable of being received by a communications interface **814**, via a communication link **816** that carries signals and may be implemented using wire or cable, fiber optics, a phone line, a cellular/mobile phone link, a radio frequency (RF) link, and/or other communication channels. Computer program instructions representing the block diagram and/or flowcharts herein may be loaded onto a computer, programmable data processing apparatus, or processing devices to cause a series of operations performed thereon to produce a computer-implemented process.

[0099] Embodiments have been described with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products according to embodiments. Each block of such illustrations/diagrams, or combinations thereof, can be implemented by computer program instructions. The computer program instructions when provided to a processor produce a machine, such that the instructions, which execute via the processor, create means for implementing the functions/operations specified in the flowchart and/or block diagram. Each block in the flowchart/block diagrams may represent a hardware and/or software module or logic-implementing embodiments. In alternative implementations, the functions noted in the blocks may occur out of the order noted in the figures, concurrently, etc.

[0100] Computer programs (i.e., computer control logic) are stored in main memory and/or secondary memory. Computer programs may also be received via a communications interface **812**. Such computer programs, when executed, enable the computer system to perform the features of the embodiments as discussed herein. In particular, the computer programs, when executed, enable the processor and/or multi-core processor to perform the features of the computer system. Such computer programs represent controllers of the computer system.

[0101] FIG. **9** shows a block diagram of an example system **900** in which an embodiment may be implemented. The system **900** includes one or more client devices **901** such as consumer electronics devices, connected to one or more server computing systems **930**. A server **930** includes a bus **902** or other communication mechanism for communicating information, and a processor (CPU) **904** coupled with the bus **902** for processing information. The server **930** also includes a main memory **906**, such as a random-access memory (RAM) or other dynamic storage device, coupled to the bus **902** for storing information and instructions to be executed by the processor **904**. The main memory **906** also may be used for storing temporary variables or other intermediate information during execution or instructions to be executed by the processor **904**. The server computer system **930** further includes a read-only memory (ROM) **908** or other static storage devices coupled to the bus **902** for storing static information and instructions for the processor **904**. A storage device **910**, such as a magnetic disk or optical disk, is provided and coupled to the bus **902** for storing information and instructions. The bus **902** may contain, for example, thirty-two address lines for addressing video memory or main memory **906**. The bus **902** can also include, for example, a 32-bit data bus for transferring data between and among the components, such as the CPU **904**, the main memory **906**, video memory, and the storage **910**. Alternatively, multiplex data/address lines may be used instead of separate data and address lines.

[0102] The server **930** may be coupled via the bus **902** to a display **912** for displaying information to a computer user. An input device **914**, including alphanumeric and other keys, is coupled to the bus **902** for communicating information and command selections to the processor **904**. Another type or user input device comprises cursor control **916**, such as a mouse, a trackball, or cursor direction keys for communicating direction information and command selections to the processor **904** and for controlling cursor movement on the display **912**.

[0103] According to one embodiment, the functions are performed by the processor **904** executing one or more sequences of one or more instructions contained in the main memory **906**. Such instructions may be read into the main memory **906** from another computer-readable medium, such as the storage device **910**. Execution of the sequences of instructions contained in the main memory **906** causes the processor **904** to perform the process steps described herein. One or more processors in a multi-processing arrangement may also be employed to execute the sequences of instructions contained in the main memory **906**. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement the embodiments. Thus, embodiments are not limited to any specific combination of hardware circuitry and software.

[0104] The terms “computer program medium,” “computer usable medium,” “computer readable medium”, and “computer program product,” are used to generally refer to media such as main memory, secondary memory, removable storage drive, a hard disk installed in a hard disk drive, and signals. These computer program products are means for providing software to the computer system. The computer-readable medium allows the computer system to read data, instructions, messages or message packets, and other computer-readable information from the computer-readable medium. The computer-readable medium, for example, may include non-volatile memory, such as a floppy disk, ROM, flash memory, disk drive memory, a CD-ROM, and other permanent storage. It is useful, for example, for transporting information, such as data and computer instructions, between computer systems. Furthermore, the computer-readable medium may comprise computer-readable information in a transitory state medium such as a network link and/or a network interface, including a wired network or a wireless network that allows a computer to read such computer-readable information. Computer programs (also called computer control logic) are stored in main memory and/or secondary memory. Computer programs may also be received via a communications interface. Such computer programs, when executed, enable the computer system to perform the features of the embodiments as discussed herein. In particular, the computer programs, when executed, enable the processor multi-core processor to perform the features of the computer system. Accordingly, such computer programs represent controllers of the computer system.

[0105] Generally, the term “computer-readable medium” as used herein refers to any medium that participated in providing instructions to the processor **904** for execution. Such a medium may take many forms, including but not limited to, non-volatile media, volatile media, and transmission media. Non-volatile media includes, for example, optical or magnetic disks, such as the storage device **910**. Volatile media includes dynamic memory, such as the main memory **906**. Transmission media includes coaxial cables, copper wire, and fiber optics, including the wires that comprise the bus **902**. Transmission media can also take the form of acoustic or light waves, such as those generated during radio wave and infrared data communications.

[0106] Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, or any other magnetic medium, a CD-ROM, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, a RAM, a PROM, an EPROM, a FLASH-EPROM, any other memory chip or cartridge, a carrier wave as described hereinafter, or any other medium from which a computer can read.

[0107] Various forms of computer-readable media may be involved in carrying one or more sequences of one or more instructions to the processor **904** for execution. For example, the instructions may initially be carried on a magnetic disk of a remote computer. The remote computer can load the instructions into its dynamic memory and send the instructions over a telephone line using a modem. A modem local to the server **930** can receive the data on the telephone line and use an infrared transmitter to convert the data to an infrared signal. An infrared detector coupled to the bus **902** can receive the data carried in the infrared signal and place the data on the bus **902**. The bus **902** carries the data to the main memory **906**, from which the processor **904** retrieves and executes the instructions. The instructions received from the main memory **906** may optionally be stored on the storage device **910** either before or after execution by the processor **904**.

[0108] The server **930** also includes a communication interface **918** coupled to the bus **902**. The communication interface **918** provides a two-way data communication coupling to a network link **920** that is connected to the worldwide packet data communication network now commonly referred to as the Internet **928**. The Internet **928** uses electrical, electromagnetic, or optical signals that carry digital data streams. The signals through the various networks and the signals on the network link **920** and through the communication interface **918**, which carry the digital data to and from the server **930**, are example forms of carrier waves transporting the information.

[0109] In another embodiment of the server **930**, the communication interface **918** is connected to a network **922** via a communication link **920**. For example, the communication interface **918** may be an integrated services digital network (ISDN) card or a modem to provide a data communication connection to a corresponding type of telephone line, which can comprise part of the network link **920**. As another example, the communication interface **918** may be a local area network (LAN) card to provide a data communication connection to a compatible LAN. Wireless links may also be implemented. In any such implementation, the communication interface **918** sends and receives electrical electromagnetic or optical signals that carry digital data streams representing various types of information.

[0110] The network link **920** typically provides data communication through one or more networks to other data devices. For example, the network link **920** may provide a connection through the local network **922** to a host computer **924** or to data equipment operated by an Internet Service Provider (ISP). The ISP in turn provides data communication services through the Internet **928**. The local network **922** and the Internet **928** both use electrical, electromagnetic, or optical signals that carry digital data streams. The signals through the various networks and the signals on the network link **920** and through the communication interface **918**, which carry the digital data to and from the server **930**, are example forms of carrier waves transporting the information.

[0111] The server **930** can send/receive messages and data, including e-mail, and program code, through the network, the network link **920**, and the communication interface **918**. Further, the communication interface **918** can comprise a USB/Tuner and the network link **920** may be an antenna or cable for connecting the server **930** to a cable provider, satellite provider, or other terrestrial transmission system for receiving messages, data, and program code from another source.

[0112] The example versions of the embodiments described herein may be implemented as logical operations in a distributed processing system such as the system **900** including the servers **930**. The logical operations of the embodiments may be implemented as a sequence of steps executing in the

server **930**, and as interconnected machine modules within the system **900**. The implementation is a matter of choice and can depend on the performance of the system **900** implementing the embodiments. As such, the logical operations constituting said example versions of the embodiments are referred to for example, as operations, steps, or modules.
[0113] Similar to a server **930** described above, a client device **901** can include a processor, memory, storage device, display, input device, and communication interface (e.g., e-mail interface) for connecting the client device to the Internet **928**, the ISP, or LAN **922**, for communication with the servers **930**. The system **900** can further include computers (e.g., personal computers, computing nodes) **905** operating in the same manner as client devices **901**, where a user can utilize one or more computers **905** to manage data in the server **930**.
[0114] Referring now to FIG. **10**, illustrative cloud computing environment **1050** is depicted. As shown, cloud computing environment **1050** comprises one or more cloud computing nodes **1010** with which local computing devices used by cloud consumers, such as, for example, personal digital assistant (PDA), smartphone, smart watch, set-top box, video game system, tablet, mobile computing device, or cellular telephone **1054**A, desktop computer **1054**B, laptop computer **1054**C, and/or automobile computer system **1054**N may communicate. Nodes **1010** may communicate with one another. They may be grouped (not shown) physically or virtually, in one or more networks, such as Private, Community, Public, or Hybrid clouds as described hereinabove, or a combination thereof. This allows cloud computing environment **1050** to offer infrastructure, platforms, and/or software as services for which a cloud consumer does not need to maintain resources on a local computing device. It is understood that the types of computing devices **1054**A-N shown in FIG. **10** are intended to be illustrative only and that computing nodes **1010** and cloud computing environment **1050** can communicate with any type of computerized device over any type of network and/or network addressable connection (e.g., using a web browser).
[0115] It is contemplated that various combinations and/or sub-combinations of the specific features and aspects of the above embodiments may be made and still fall within the scope of the invention. Accordingly, it should be understood that various features and aspects of the disclosed embodiments may be combined with or substituted for one another in order to form varying modes of the disclosed invention. Further, it is intended that the scope of the present invention herein disclosed by way of examples should not be limited by the particular disclosed embodiments described above.

Claims

1. A system comprising: a processor having addressable memory, the processor in communication with two or more relays, wherein the processor is configured to: store a first state based on an order of two or more relays to be switched on; send one or more first signals to switch on a relay of two or more relays based on the stored first state; wait for a set time after sending each first signal of the one or more first signals; and update the first state based on the order the one or more first signals were sent.
2. The system of claim 1, wherein the processor is further configured to: store a second state based on an order of two or more relays to be switched off; send one or more second signals to switch off a relay of two or more relays based on the stored second state; wait for a set time after sending each second signal of the one or more second signals; and update the second state based on the order the one or more second signals were sent.
3. The system of claim 1, wherein the set time is greater than an operating time of each relay of the two or more relays.
3. The system of claim 1, wherein the set time is based on a transfer time of the two or more relays and a system power cycle time.
4. The system of claim 1, wherein the order of the two or more relays to be switched on is in a

variable sequence determined by the first state.
5. The system of claim 1, wherein the two or more relays are in an electric vehicle supply equipment (EVSE).
6. The system of claim 1, wherein the processor is further configured to: check a status of the two or more relays after the one or more first signals were sent.
7. The system of claim 1, wherein the stored first state is configured to vary which relay of the two or more relays is turned on as a first relay to be turned on, and wherein the stored first state is configured to reduce early degradation of a relay of the two or more relays in relation to other relays of the two or more relays.
8. The system of claim 1, wherein the two or more relays comprise two relays, wherein a first first signal of the one or more first signals is configured to turn on a first relay of the two or more relays based on the stored first state, wherein a second first signal of the one or more first signals is configured to turn on a second relay of the two or more relays based on the stored first state.
9. The system of claim 8, wherein the first first signal of the one or more first signals is configured to turn on the second relay of the two or more relays based on the updated first state, and wherein the second first signal of the one or more first signals is configured to turn on the first relay of the two or more relays based on the updated first state.
10. A system for controlling a plurality of electrical switches, each electrical switch having two or more operational states and responsive to control signals for changing between operational states, the system comprising: a controller configured to generate control signals to selectively change the operational state of one or more of the electrical switches based on at least one of: a selected timing and a selected sequence; wherein the selective changing of the operational state of the one or more of the electrical switches is configured to reduce early degradation of the one or more of the electrical switches in relation to said plurality of electrical switches.
11. The system of claim 10, wherein the controller is further configured to generate control signals to selectively change the operational state of one or more of the electrical switches based on a selected timing as a function of the operational characteristics of one or more of the electrical switches.
12. The system of claim 11, wherein the controller is further configured to selectively change the operational state of one or more of the electrical switches based on a selected timing as a function of said operational characteristics including one or more of: power cycle time and switch transfer time.
13. The system of claim 10, wherein the controller is further configured to generate control signals to selectively change the operational state of one or more of the electrical switches in a variable sequence.
14. The system of claim 13, wherein the controller is further configured to generate control signals to selectively change the operational state of one or more of the electrical switches in a variable sequence based on selected timing as a function of one or more of: power cycle time and switch transfer time.
15. The system of claim 10, wherein the controller is configured to generate control signals to change the operational state of one or more of the electrical switches in an alternating sequence.
16. The system of claim 15, wherein the controller is further configured to change the operational state of one or more of the electrical switches in an alternating sequence based on selected timing as a function of one or more of: switch transfer time and system power cycle time.
17. The system of claim 10, wherein the controller is further configured to change the operational state of each of the electrical switches based on a selected timing and selected sequence to prevent one or more of the electrical switches from early degradation in relation to the other electrical switches in the system.
18. A system comprising: a plurality of electrical switches, each electrical switch having two or more operational states and responsive to control signals for changing between operational states; a

controller configured to generate control signals to selectively change the operational state of one or more of the electrical switches based on at least one of: a selected timing and a selected sequence, to reduce early degradation of one or more of the electrical switches in relation to said plurality of electrical switches.

19. The system of claim 18, further comprising: N relays; a state counter C that cycles through counts 1, 2, . . . , N, 1, 2, . . . , N, 1, 2, . . . , N, wherein the controller is further configured such that in a power cycle: in a control state C, upon receiving a power on signal, a relay C is turned on first, and then subsequent relays are turned on in sequence after a set wait time has passed for each delay; in the control state C, upon receiving a power off signal, relay C is turned off first, and then subsequent relays are turned off in sequence after a set wait time has passed for each; the state counter is incremented by one, such that when C=N, the state counter C is reset to 1.

20. The system of claim 19, wherein the set wait time is a function of at least one of: relay transfer time and system power cycle time.