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(54) Title: A STANDALONE SELF-SUPPLIED NUMERIC CONTROLLED RELAY

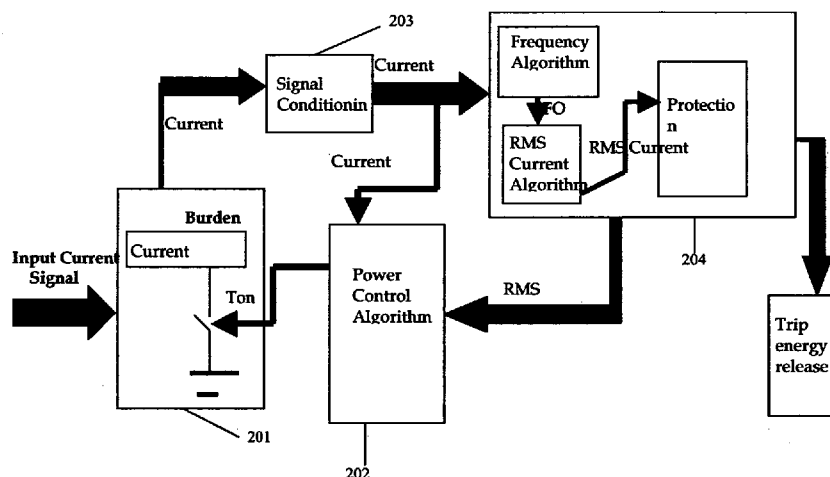


FIGURE: 2

(57) Abstract: The invention relates to a process of configuring a standalone self-supplied numeric controlled relay for providing phase and earth over current protection to electrical systems by accurate current measurement. The arrangement for current measurement with control algorithms is provided for power control by providing amplified and conditioned current for optimization between the current necessary to power an electronic circuit and the fidelity of a measured current waveform so that they both are at the acceptable levels at the same time. This invention disclosure describes the current sensing and associated algorithm for power control in a truly self-powered relay.



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A STANDALONE SELF-SUPPLIED NUMERIC CONTROLLED RELAY

5 FIELD OF INVENTION

The present invention relates generally to circuit interruption arrangements and more particularly to current measurement and sensing arrangements such as used by circuit breakers and overload/over-current relays which are powered from the circuit path they are arranged to
10 interrupt (self-powered).

BACKGROUND OF INVENTION

The use of relay is widespread in modern-day residential, commercial and industrial electric
15 systems and they constitute an indispensable component of such systems for providing protection against over-current conditions and earth-fault protection. In power system protection traditionally static auxiliary powered relays for over-current and earth-fault protection are used. In such designs, the source of energy required by an electronics circuit is independent of current sensors. The current sensors in this situation encounter very low and constant burden and small
20 linearity range, generally 20 times of the nominal design current, which facilitates the secondary current waveform to be free of any significant distortion. The current sensors are therefore light in weight and smaller in size. Also the current sensors follow primary high current sensors. Further, for measurement of the current through the current sensors, the control electronics derives the operating power from an auxiliary power supply, which facilitates realization of an active filter
25 design including signal conditioning. The auxiliary power supply supplements usage of dual polarity voltage supply enabling implementation of a simple and active filter conditioning. Further, the high power demand of electronics circuit can be supplied easily. In other words, a design flexibility in terms of components selection and features to be embedded is available.

30 There are however certain situations, where an installation encounters constraint for supporting auxiliary power supply for the relay operation (for e.g. Ring Main Units installation in urban cities) and hence need arises for a self powered relay per se. However, in case of self powered relays per se, the energy required by the relay electronics circuit is to be supplied with at least one measuring current sensor. It implies interalia that the current sensors must provide measurement

of current including power supply. Thus, based on the power consumption requirement of the control electronics, the current sensors VA capacity is influenced. Further, the very approach for power extraction from the current sensor also introduces distortion in the basic current sensor waveform due to dynamic impedance faced by the sensor owing to the requirements for
5 restricting the power dissipation over the operating current range. Such a requirement calls for current sensors with greater VA capacity and greater linearity range. The current sensors required are therefore bulky. To achieve the best relay performance in this situation with least possible current sensor size and VA, optimal balance of the control electronics design hardware and the associated software needs to be achieved.

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US patent 7,304,828 discloses an AC/DC intelligent solid state relay/breaker device with current/temperature sensing, time-delay overloads and over-current/over-temperature protection. In this invention, power MOSFETs or other transistors, control a load current. A bypass current sensing path monitors the MOSFET current and causes a shutdown through signal processing in
15 the event of an over-current condition. However, it does not provide for phase and earth fault protection since it is meant to be used as series element in power flow configuration.

15

US publication 20060007627 discloses an intelligent MOSFET based relay system that responds to a variety of influences. The relay system includes at least one relay, at least one peripheral
20 sensor collecting data related to the relay system, and a control logic section linked to the relay and the sensor. The control logic section is further linked to a control computer via a communication interface. The control logic section includes means for intelligently controlling operation of the relay based upon instructions received from the control computer and data collected via the at least one peripheral sensor and the relay. The system is further adapted for use
25 in a networked arrangement. This patent talks about control computer passing instructions for controlling operation of relay.

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Patent no. WO/2007/114951 is in the field of industrial control systems, protection and control mechanisms and/or methodologies for electrical motors and other electrical devices. It can
30 substantially satisfy many of the needs unfulfilled by the prior art mechanisms for the protection and control of electrical devices and can provide for wide-range current measurement, self-calibration, and wide-range line-powered electronics to provide application flexibility and reliability, cost-effectiveness. An overload relay can be employed along with an electromagnetic

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contactor, consistent with the application, as a component in industrial control systems. However, this patent talks about usage of auxiliary supply with applications for electrical motors.

5 US patent 7,016,174 describes a system for an electronic trip unit whereby reliable instantaneous protection is provided. A multi-algorithmic approach uses an algorithm to detect bolted faults based on a direct comparison of the current and a threshold value, and an additional algorithm to detect current overloads based on a comparison of a peak-to-peak current and an additional current threshold. However the patent does not provide user configurability.

10 In the US patent 7,248,451 a power controller is positioned within a current path between the line side and the load side of an electrical circuit. The power controller closes the current path in the presence of a control supply and opens the current path in the absence of the control supply. A power supply electrically connected to the current path provides the control supply. A sensor system receives power from the power supply, monitors the current in the current path and
15 outputs a sensor signal indicative of a current condition within the current path. A logic controller also receives power from the power supply, receives the sensor signal and removes the control supply from the power controller when the sensor signal does not satisfy established criteria. The sensor system may include either or both of imbalance sensors for monitoring the current balance among two or more electrical lines and over-current sensors for monitoring current in individual
20 lines. However, the control of the supply- auxiliary power source indicates that the current relays used in the sensor system do not constitute a self-powered relay per se.

US publication 20060050464 relates generally to a control system, and, more particularly, to a control system having a solid state relay in a hockey puck configuration for controlling power to a
25 power-receiving load. The first bus bar and the second bus bar are configured to include a current sensing portion. It has communication interface adapted for compatibility with a communication selected from the group consisting of a WatBus.TM, Dallas Semiconductor one-wire protocol, a Seriplex, a sensor bus, a DeviceNet.TM. bus, a FMS, Lon Works, a Control Area Network (CAN), an Interbus S, an SDLC, AS-Interface (AS-i), a Local Interconnect bus (LIN-bus), an
30 IEEE-1118 bus, a Profibus, Modbus RTU, an enterprise communication bus including an Ethernet TCP/IP, an Internet, a token ring LAN, an Ethernet LAN, an FDDI network, a private data network, an ISDN, and a VPN. However, this patent talks about solid state relay with variety of custom communication.

US patent 7,031,131 relates to an over-current protection device for detecting a current flowing through a conductor and for shutting of the current when the current exceeds a predetermined threshold value. A current sensor which constitutes an overload protection apparatus and senses a current supplied from a power source to a load is constituted by providing a magnetic sensor
5 having the effect of magnetic impedance (MI), an AC supply means which impresses AC on this sensor, a bias current supply means which supplies a bias current to a bias coil, a peak sensing means which senses the peak or a change in impedance of the magnetic sensor as a change in voltage, and a switch which selects the output of the peak sensing means in accordance with each phase. A holding means which holds switch outputs one after another and an amplification means
10 are provided in common to enable current sensing for each phase. Thus, a range of current sensing is enlarged to reduce power consumption and cost. However this invention uses AC supply to impress the sensor. It also uses bias current supply for biasing bias coil.

US patent 6,888,712 relates to a single protection device, including a transformer, an input
15 circuit, and a switch circuit, suitable for addition to an electrical power system that includes a control panel electrically interconnected with a starter to control an electrical device. The patent talks about starter with varied functional blocks.

US patent 6,421,216 discloses an overcurrent protection system giving rapid response to
20 relatively small overcurrents. It has a sensor element and an interruption element in series between a power source and a load. The sensor element is functionally linked to the circuit interruption element via a control element. When current exceeds a predetermined amount, the sensor element transfers heat to the control element, which causes the circuit interruption element to change from a conducting state to a non-conducting fault state. The control element may
25 include a PTC device. However, the patent talks about thermal considerations-heat transfer for operations and is not based on electrical sensing of current magnitudes through interfacing current transformers.

US patent 6,055,145A describes a microprocessor based overcurrent trip unit which generates trip
30 signals as an adjustable function of current and time, has a visual representation of the trip function on a front panel with 2-color LEDs associated with the trip function serving as indicators of trip conditions when red, and of a selected programmable parameter when green. The green LEDs flash to indicate parameter selected for modification in a program mode and illuminate steady in a view mode. However, it does not provide any indication of source of power.

US patent 6,459,557 discloses a configurable overload relay selectively operable in a single-phase mode of operation and a multi-phase mode of operation configured to sense current flow through power conductors. The relay is further configured to determine a parameter related to the current flow, such as average current, vector sum of phase currents, and current imbalance, based on selection of either the single-phase or multi-phase mode of operation. Regardless of the selected mode of operation, the relay can provide protection for multiple types of power conductor fault conditions, including ground faults, overloads, and phase loss. The relay further can be configured to provide a reporting signal indicative of the value of the determined current-related parameter and/or the occurrence of the fault condition. Thus the patent has two distinct mode of operation.

Patent no. RU2179775 discloses reference-voltage source and 2(two) AND gates whose output is connected to input of final element; its first input is connected to output of OR gate and second input, to one of outputs of signal shaper that functions to record critical overcurrent; other outputs of signal shaper are connected to respective inputs of time-setting circuit and the current sensor is inserted in series with circuit under protection. First inputs of signal shaper are connected to its output through voltage divider and its second ones, to respective levels of reference voltages. In this way device provides for protecting DC and AC power circuits and realizes single-valued current and time settings due to discrete principle of control. However, the patent has protecting DC and AC power circuits with gated logic without any mention of operating source of power.

US patent 4,077,055 provides a self-powered self-contained ground fault protective device including a current monitor, an electronic circuit for amplifying the output of the current monitor, a relay connected to the amplifying circuit and adapted to operate whenever the ground fault current, through the current monitor, rises above a predetermined level, and an interchangeable rating plug including means for activating a circuit board switch. The current monitor, amplifying circuit, and relay are all supported and enclosed by a molded insulating housing. The rating plug is inserted into a socket on the exterior of the housing. However, this patent appears to be more of mechanical plug in construction for ground fault instead of truly self powered relay well suited for phase faults too.

Patent no. EP0469207 discloses a self powered multiple phase circuit protection devices including a plurality of current transformers connected in parallel with each other and adapted to

be individually associated with one phase of a multiple phase load and for providing signals representing the current flowing in an associated phase. A switch is adapted to be actuated to interrupt power to the multiple phase loads and a fault determining circuit is connected to the circuit transformers and to the switch for actuating the switch for at least one predetermined
5 condition of the current signals. However, the functionality disclosed is average current based and thus different from the present invention.

Thus, none of the prior art systems teaches or suggests a self-supplied standalone numeric controlled relay with accurate current measurement, optimum VA-capacity and linearity range
10 adaptable for phase and earth fault protection.

To generate power from a current source, the current waveform must be rectified and energy stored into a capacitor. It can be proven that for a given current by an infinite current source, the full wave rectified current can support only definite amount of power at a definite bus voltage.
15 The bus voltage changes as soon as the power demand changes provided the source current remains constant. Thus, to support a lower setting current, it is required that the power demand of relay electronics circuit is minimum. The full wave rectified current generates only a positive voltage energy source. Generating negative voltage from the positive voltage energy source is loss of energy. This imposes a restriction on dual polarity supply availability for current signal
20 conditioning. Even if dual polarity supply is used, the current shall be measured in differential mode across the current sensor secondary (prior to full wave rectifier). This further complicates the measurement circuit implementation and cost for that reason. One of the suitable ways is to measure current by putting a shunt in series with rectifier circuit.

25 The secondary current of the current sensor, if interrupted, shall result into destructive high voltage generation across the secondary terminals. The maximum current demand of the relay electronics circuit is limited. As the current source is an uninterruptible source of energy, at higher currents, the energy in the capacitor, after rectifier, increases if the power demand by electronics circuit is less than power input. This results in incremental high voltage generation
30 across the capacitor leading to damage to itself and rest of the electronics circuit. Thus, means for diverting excessive energy back to the source with low impedance, is essential.

As the load on the CT-secondary changes, it's magnetization requirement changes. This results into a variable secondary current. This effect is more prominent at lower line currents when power control switch on times are small.

- 5 There have been few products from the applicant, and other competitive manufacturers, which support the truly self power operation. With all the above discussed restrictions or limitations imposed by self powered relay configuration on measurement and power control, it is required to have greater accuracies for protection functions.

10 OBJECTS OF THE INVENTION

It is therefore an object of the invention to propose a process of configuring a stand-alone self-supplied numeric controlled relay for providing phase and earth over current protection to electrical systems by accurate current measurement.

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Another object of the invention is to propose a process of configuring a stand-alone self-supplied numeric controlled relay for providing phase and earth over current protection to electrical systems by accurate current measurement which exhibits optimum VA-capacity and linearity range.

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A still another object of the invention is to propose a process of configuring a stand-alone self-supplied numeric controlled relay for providing phase and earth over current protection to electrical systems by accurate current measurement, which does not require any auxiliary power supply to operate the internal electronic circuit.

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A further object of the invention is to propose a process of configuring a stand-alone self-supplied numeric controlled relay for providing phase and earth over current protection to electrical systems by accurate current measurement, which is compact, and derive power from the current sensing transformers.

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SUMMARY OF THE INVENTION

The present invention relates to a process for configuration of a phase and earth over-current protection relay to electrical systems by accurate current measurement. It is a self powered relay

and does not require any auxiliary power supply to operate the electronics circuit within. It derives its operating power from the current sensors itself. It requires minimum current in at least single phase to start on. The current is 60mA, which is sum of the phase current through MOSFET irrespective of the individual phase current magnitude. It is suitable where no auxiliary power available as the relay derives power from the current sensing transformers. Current setting range is from 7.2A to 8960A that is divided in 5 different ranges supported by 5 set of current transformers. It provides earth current measurement through internal soft calculation or external current transformer (Core Balance Current Transformer) with 1Amp nominal secondary current.

The present invention provides an arrangement for accurate current measurement with control algorithms for power control by providing amplified and conditioned current for optimization between the current necessary to power an electronic circuit and the fidelity of a measured current waveform, so that they are both at acceptable levels at the same time. This invention describes the current sensing and associated algorithm for power control in truly self powered relay.

According to an advantageous embodiment of the invention, the relay senses the phase currents through three phase current sensors.

According to another embodiment of the invention the relay estimates earth current internally through soft calculations.

According to a still another embodiment of the invention the earth current measurement is possible through external earth current interface also. Either of internal or external earth current measurement is possible and is selectable.

In a further embodiment of the invention the reference current for the relay can be set through mechanical DIP switches. If the sensed current exceeds the reference current, the relay releases trip energy after specific time duration depending upon the selected time-current characteristic.

In a still embodiment of the invention, the released energy can be supplied to trip coils of circuit breakers to clear the over current fault.

According to the invention the relay accepts remote tripping command also termed as binary Input, and for every trip generation, the relay sets an indicator termed as flag or flip indicator,

which can be reset using push button interface when the system and the relay are healthy and functional.

- 5 In case of any internal relay fault (hardware and software) the relay generates an Internal Relay Fault indication.

The relay senses DC offset, inrush current, THD (Total Harmonic Distortion), frequency change (45Hz to 65Hz), and supports as many as eight selectable fault characteristic curves both for phase and earth fault clearance.

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The relay is adaptable in Ring Main Units (RMU) within the distribution network, and provides energy release for trip coil used in RMU.

The relay can be used in secondary distribution and in primary distribution as well.

15

The relay has use in system protection and control, and design concepts as well as algorithms can be adapted for transducers and metering purposes, including signaling and control applications, industrial instrumentation, process automation.

- 20 The invention provides different IDMT (Inverse Definite Minimum Time) curves for both phase and earth over current protection including providing remote trip input, unit ready and internal relay fault indications through the LEDs.

- 25 The invention also provides phase and earth over current fault indication through a manually resettable electromechanical FLAG, and a coarse current setting through mechanical binary (DIP) switches in base version.

- 30 The invention also provides interface for finer settings and data retrieval through battery powered add on human-machine interface (HMI) with keyboard and display, including test inputs for on site testing of individual phase/earth channel and relay functionality up to trip output.

The invention provides fail safe trip release when micro controller fails and phase currents are reaching 20 times the rated current of current transformers. For fault currents above 20 times the rated CT current, the relay releases trip with 40msec delay.

In the present invention, a current measurement and sensing arrangement has been developed using control algorithms including: MOSFET and Darlington pair circuit to control power and protect the electronics circuit, another circuit or a computer/ microprocessor, a power supply including a capacitor arranged to accumulate charge, a current sensing shunt resistor and current
5 sensing circuit. It has a micro-controller to monitor the quality of grid power and same realizes the protection function of the connected equipments.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS:

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FIG. 1 shows a block diagram of current sensing relay/switch mechanism, control and display arrangement

FIG. 2 shows a schematic diagram of the process according to the invention.

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FIG. 3 shows a flow-chart for the power control according to the invention.

FIG. 4 shows a flow-chart of RMS current estimation according to the invention.

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FIG. 5 shows a flow-chart of a protection scheme according to the invention.

Fig. 6 shows indicative diagram for power extraction and current sensing scheme according to the invention.

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Fig. 7 shows power distribution scheme according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS:

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FIG. 1 illustrates a block diagram of power control, current sensing, switch mechanism, control and display arrangement for a self powered relay 10. This relay 10 operates without any auxiliary power supply. It derives power for relay electronics circuit from the current sensors itself.

The power supply **100** is prepared by rectifying current from the current sensors with the help of a full bridge rectifier and storing it in to a bus capacitor. All the three phases are connected in parallel with respect to the capacitor.

- 5 The bus capacitor voltage is 24V under normal operating conditions. It gets reduced to +3.3V by using a switching regulator. The +3.3V supply is being used for a micro controller **101** and peripherals. There is another +12V supply made available using a linear regulator from 24V bus voltage. The +12V supply is being used for supplying to the analog current sensing circuit **102**, FLAG operation energy storage **104** and trip coil energy reservoir **105**. From regulated +12V, a
10 reference voltage of +3.3V for the controller **101** gets generated through linear regulator.

- There is a shunt in series with the current path of the current transformer (CT) secondary. The shunt converts current signal in to voltage signal. The voltage signal gets divided using a potential divider. There is a spike suppressor across current sensing network **102**. The conditioned current
15 after operational amplifier stages is fed to a built-in A/D converter of the micro-controller **101**. The same voltage signal across the shunt goes through zero cross detection network to the A/D converter to the micro-controller **101**. The micro-controller **101** based on above information monitors line current and line current frequency.

- 20 The micro-controller **101** monitors line current and its quality. It detects the dc offset present in current waveform. DC offset arises in the system in case of any fault leading to over current. It also detects in-rush current. In-rush current arises in the system in case of hard switching on of any highly inductive load. It further detects THD present in the system. Harmonic distortion arises in the system due to switching loads like inverter etc. The micro-controller **101** senses over
25 current situations in the system. The over current situation is defined as line current greater than set current fed to the micro-controller **101** through mechanical DIP switches **107**. In case of over current situations, the micro-controller **101** checks for presence of DC offset, in rush current and THD present in the line current. Micro-controller **101** discounts effects of DC offset, in rush current and THD up to 30% to calculate over current conditions. In case of estimated over current
30 condition, the micro-controller **101** releases trip energy to a switch mechanism out side the relay **10** that further isolates the equipment or section of power system from over current fault condition. The micro-controller **101** gets set current information from the DIP switch matrix **107**.

The micro-controller **101** also accepts conditioned signal from remote location **103** through binary input BI section. On receipt of signal from BI section, the micro-controller **101** releases trip energy to the external switch mechanism.

- 5 The micro-controller **101** is able to communicate with battery **108** powered add on HMI unit **112**. The same communication port is being exploited for production time testing. This communication port is not available for the user.

- 10 The micro-controller **101** issues a FLAG set **104** signal to set externally visible FLAG in the event of trip energy release **105** by any means. It also acknowledges FLAG reset **104** signal from an external push button **109** and resets FLAG.

- 15 In case of all healthy condition of hardware and software, the micro-controller **101** enables unit ready LED **106**. In case of unhealthy condition of hardware or software, the micro-controller **101** enables internal relay fault LED **110**.

- 20 In the present invention, LPC 2138 micro controller **101** from NXP (earlier Phillips Semiconductors) based on ARM 7 architecture has been used. The controller **101** is programmed to achieve the functionality as described by specialized embedded code involving the above described functions and the basic functionality of product.

- 25 Front panel components for base relay include indications through LEDs **106**, bi-settable flag **104**, DIP switches **107**, push button **109** and multi pin connectors. Add-On module interface on the rear side has matched mating connector for interfacing with the base relay. RS232 communication interface **111** is provided to connect the controller **101** with LCD push button interface and communication interface **112**.

Fig. 2 describes the process according to the invention, which is as follows-

- 30 1) Block **201**: Burden

The burden **201** consists of switching load in series with current sense shunt resistor. When switch is ON, whole load is bypassed and when switch is OFF whole load, in series with shunt resistor for current sensing, appears across current transformer secondary. The current sense resistor converts current signal in to voltage signal.

2) Block 202: Power Control Algorithm

The block 202 decides switching device "ON time" to control power and measure current. A separate fig for power control algorithm is shown in fig. 3. This block takes three phase RMS
5 current as input signal and based on the algebraic sum of all three phase current 301, control algorithm decides "ON time" or switching time 302 for the switching elements.

3) Block 203: Signal conditioning

Only single polarity voltage is generated. Hardware filtration of current signal is not possible due
10 to the various reasons. Only high frequency current spikes can be filtered through ceramic capacitors across the current sense resistors. The sensed currents are passed through three different gain amplifiers to get optimal signal amplitude for measurement over the whole operating current range of 75mA to 5.83A. The same signal across the current sense resistor is used to identify zero cross over. This is required for frequency estimation as well for current
15 measurement algorithms.

4) Block 204: Relay Algorithm.

This block 204 contains mainly digital signal processing modules and also contains the protection algorithm (separately shown in fig. 5) and on that basis it generates trip signal. This block
20 contains frequency estimation, RMS Current estimation and protection modules. Based on the frequency estimation whole software synchronizes with the estimated frequency.

Referring to Fig.4, based on frequency estimation by frequency algorithm 401, RMS current algorithm 402 computes RMS value of the input current signal, which is the deciding parameter
25 for the power control as well as trip signal generation.

Protection algorithm 501 is shown in Fig.5. Here RMS current algorithm also takes care of DC offset calculation, Inrush current identification & the Total Harmonic Distortion (THD) estimation.
30

Accurate current measurement in self powered relays using unique current sensing and power control algorithm is discussed below.

Referring to Fig. 6, indicative diagram for power extraction and current sensing scheme 601, the three phase currents I1, I2, I3 are rectified to charge the bus capacitor C1 in parallel. The full wave rectified current is sensed with reversed ground. The filtered (noise filter RC) negative current with respect to ground is reversed through front end single supply OP AMP (operational amplifier) stage and conditioned to be able to be read by the controller. As discussed in previous sections the load impedance is variable due to charging and discharging profile of the capacitor voltage. For measurement purpose it is required that the impedance seen by current source remains constant. This is the case when MOSFET M1 is ON. Therefore, current measurement must happen when MOSFET M1 is ON. For measurement the MOSFET M1 is made ON for specific duration (say 100µsec at least) at a rate of 20 samples per cycle. All the three phase currents I1, I2 and I3 are sensed during this period. However, MOSFET M1 ON time can be greater than 100µsec depending upon the source current.

Power distribution system is shown in Fig. 7. The sensed bus voltage via a potential divider is given to the controller. The bus capacitor voltage 701 is 24V under normal operating conditions. The current sensing scheme exploits only single polarity (+ve) supply. The bus voltage is fed to a +12V liner regulator 702 to generate power for analog circuit (current conditioning circuit), the trip release reservoir and trip indicator flag reservoir. The same bus voltage is fed to the switching regulator 703 that generates +3.3V for logic level digital circuits (controller and peripherals). +3.3V linear regulator 704 follows the regulated +12V for +3.3V reference generation.

Power control:

The power input source is a definite set of current transformers for each phase. At a time, one set of current transformers is used. There could be a possibility that only one of the three phases is available. The electronic circuit must be functional in such condition also. As the output of the current sensor depends upon input current and it cannot be kept open or exposed to high impedance, the current loop must get closed. At the same time, as the current loop cannot be interrupted, the energy transfer is continuous and it increases as the input current increases. If the energy is not controlled or dissipated, the bus voltage increases indefinitely as the power requirement from electronics circuit is limited. This finally results in to failure of capacitor and electronics circuit.

The one of the possible option is to supply excessive current from source with low impedance (low impedance bypass is required to avoid heat dissipation) back to the source. This is done by using very low impedance MOSFET M1 across the bus capacitor C1. The diode D6 is used to avoid bus capacitor energy release through the MOSFET M1 when it is on.

5

PWM algorithms for power control:

As the current requirement from electronics load is defined, the voltage level across the bus capacitor is indicative of energy available from source. As load current is constant, power depends upon bus voltage available. As per power demand, the energy level in the capacitor changes with time. This results in variation of capacitor bus voltage. If the power demand is constant, the additional energy results in increment of voltage across the bus capacitor. Similarly, if the power demand is constant and there is reduction in input energy to the bus capacitor, it results in the reduction in voltage level of the bus capacitor. In present case, input current from current sensors for three phases is indicative of energy insurgence from source. This effect is basis for indirect bus voltage control algorithm.

The individual phase current is sensed and based on algebraic sum of three phase current through MOSFET M1 the fixed duty cycle PWM pattern is generated. This avoids unbalanced impedance seen by current transformer for positive and negative half cycle. Such an algorithm controls power dynamically as well as avoids current sensor saturation. With this type of control in actual relay hardware, the bus capacitor voltage is kept greater than 22V. It is then controlled at around 24V by zener diode D5 along with Darlington pair transistor Q1.

For measurement purpose it is required that the impedance seen by current source remains constant. This is the case when MOSFET M1 is ON. Therefore, current measurement must happen when MOSFET M1 is ON. Due to this, the MOSFET M1 is made on for specific duration (say 100μsec) at a rate of 20 samples per cycle. All the three phase currents are sensed during this period.

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According to the other embodiments of the present invention, the system has other advantageous feature like indications and push buttons. Green LED is for relay protection function ready indication and red LED is for internal relay fault indication. Bistable flag is for latched trip indication, which is resetable by user using push button. The invention also includes 46 DIP

switches divided in 13 different subgroups for the relay settings required by user. There is provision for flag reset without removing front cover and the relay can be reset only when it is powered on and ready. Multi-pin connectors provide add-on module interface by having a communication port/ production testing communication and battery interface to power add-on module via base relay circuit board.

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CLAIMS:

1. A process of configuring a standalone self-supplied numeric controlled relay for providing phase and earth over current protection to electrical systems by accurate current measurement, comprising the steps of:
- preparing a power supply by rectifying the current from at least one current sensor by means of a full-bridge rectifier;
 - storing the prepared power supply into a bus capacitor, all the three phases being connected in parallel with respect to the capacitor;
 - reducing the bus capacitor voltage from 24V to +12V at a first stage by adapting a first linear regulator, the +12V being supplied to an analog sensing circuit, a trip coil energy reservoir, and a FLAG operation energy storage;
 - reducing the regulated voltage from +12V to +3.3V at a second stage by adapting a second linear regulator; the +3.3V being supplied to a microcontroller as reference; and
 - providing a shunt in series with the current path of the current transformer (CT) secondary to convert current signal to voltage signal;
 - providing a potential divider and a spike suppressor across the current sensing network for dividing the voltage signal and the conditioned current being supplied to the microcontroller including the voltage signal, the microcontroller monitoring line current and line current frequency.
2. The process as claimed in claim 1, wherein the monitoring of line current frequency comprises estimating the over-current condition through sensing by the microcontroller even in the presence of dc-offset, in-rush current, and THD, and releasing trip energy in case of over-current condition to a switch mechanism disposed outside the relay.
3. The process as claimed in claim 1 or 2, wherein the micro controller releases trip energy on receipt of conditioned signal from remote location in a binary input section.

4. The process as claimed in claim 1, wherein the micro controller is enabled to communicate with a battery-power add-on HMI unit.
- 5 5. The process as claimed in any of the preceding claims wherein the microcontroller on release of trip energy issues a flag-set signal and acknowledges a flag-reset signal from an external push button to reset the flag.
- 10 6. The process as claimed in any of the preceding claims, wherein the microcontroller enables a LED to indicate unit-ready signal when the hardware and software structure of the relay is in healthy state, and wherein the microcontroller enables a LED to indicate internal-relay fault when the hardware and/or software is in an unhealthy state.
- 15 7. The process as claimed in claim 1, wherein the support software structure for the relay provides for power control, signal conditioning, calculation modules for dc offset, in-rush current, and total harmonic distortion, and relay protection.
- 20 8. A process of configuring a standalone self-supplied numeric controlled relay for providing phase and earth over current protection to electrical systems as substantially described and illustrated herein with reference to the accompanying drawings.

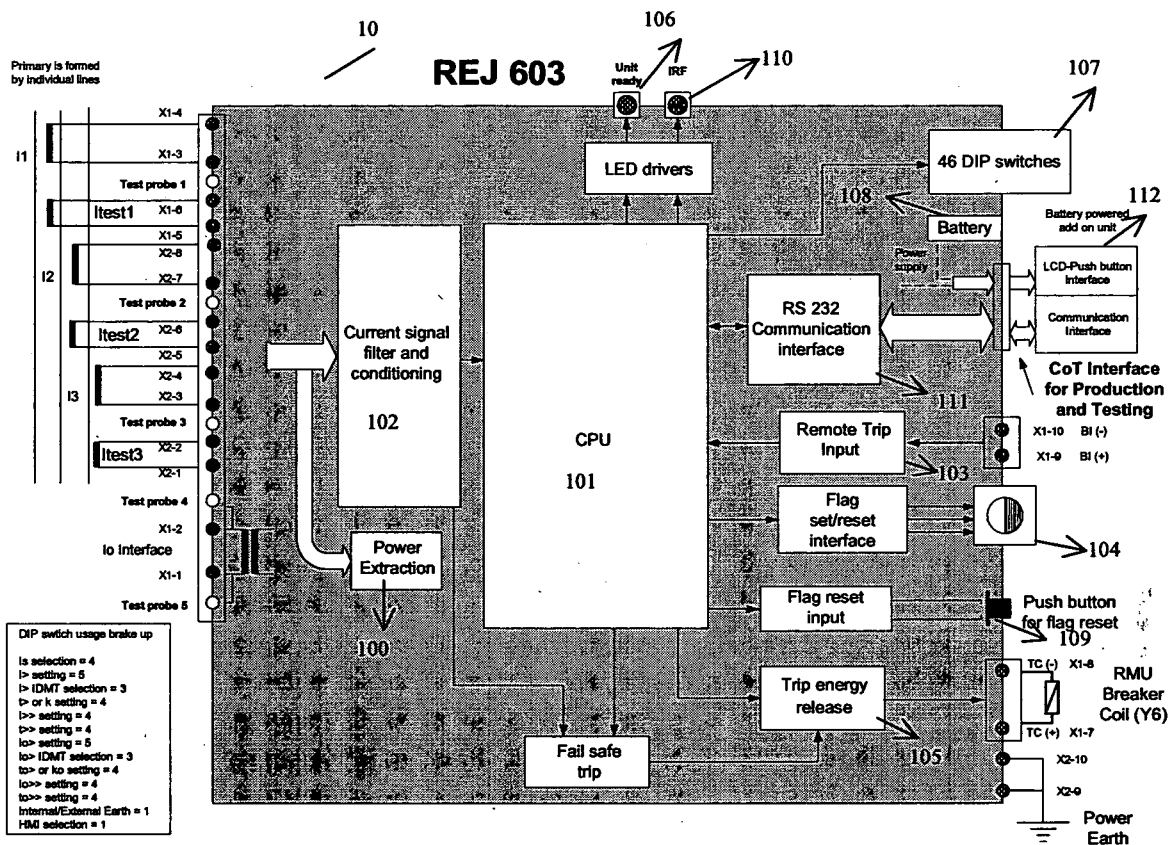


FIGURE: 1

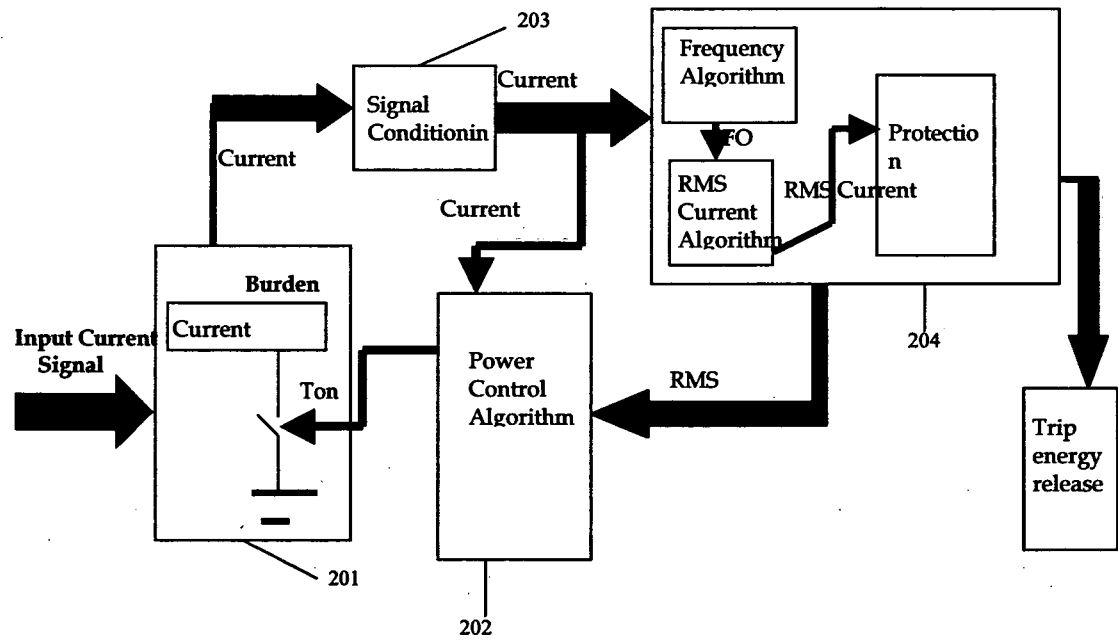
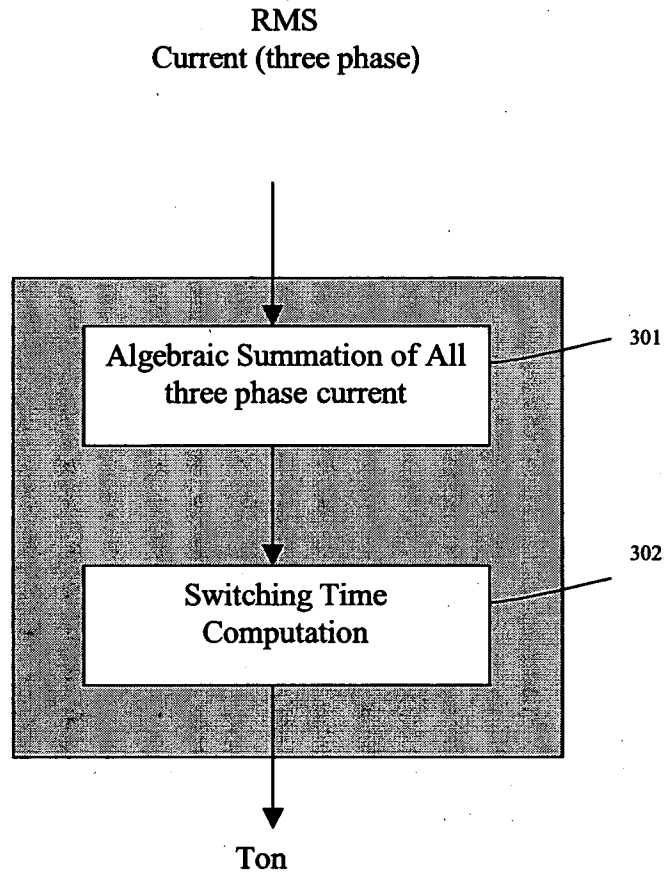
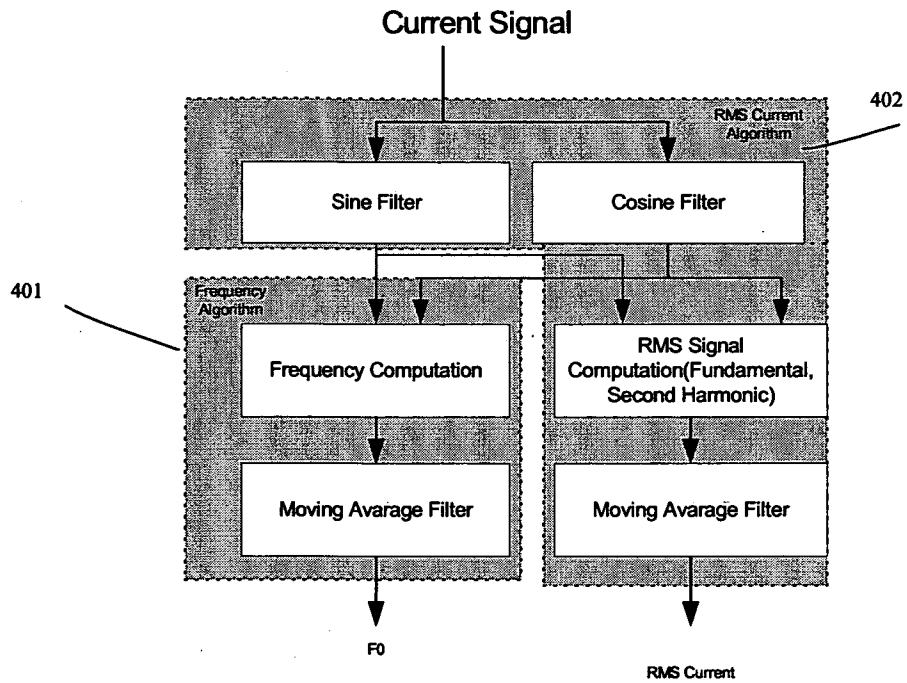
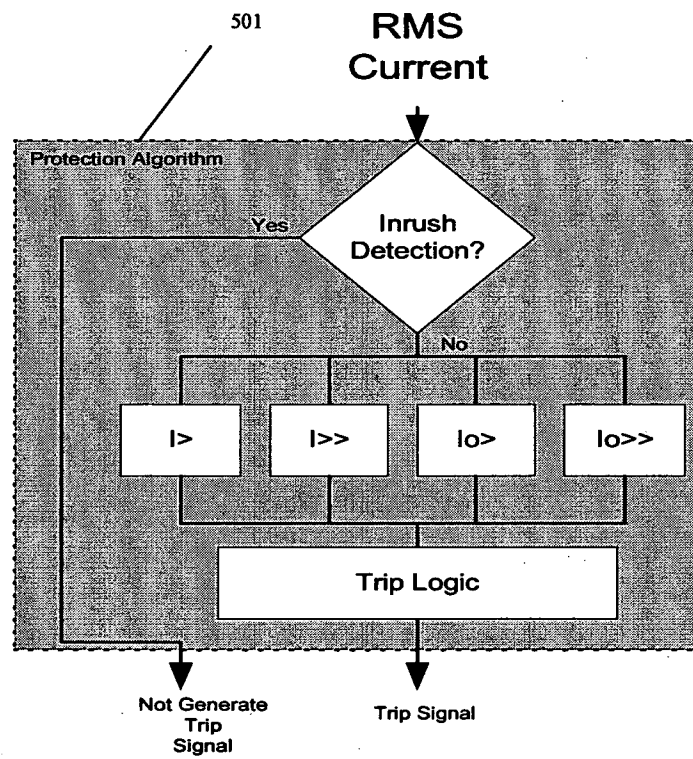


FIGURE: 2

**FIGURE: 3**

**FIGURE: 4**



I> = Low set current setting
I>> = High set phase current setting
Io> = Low set earth current setting
Io>> = High set earth current setting

FIGURE: 5

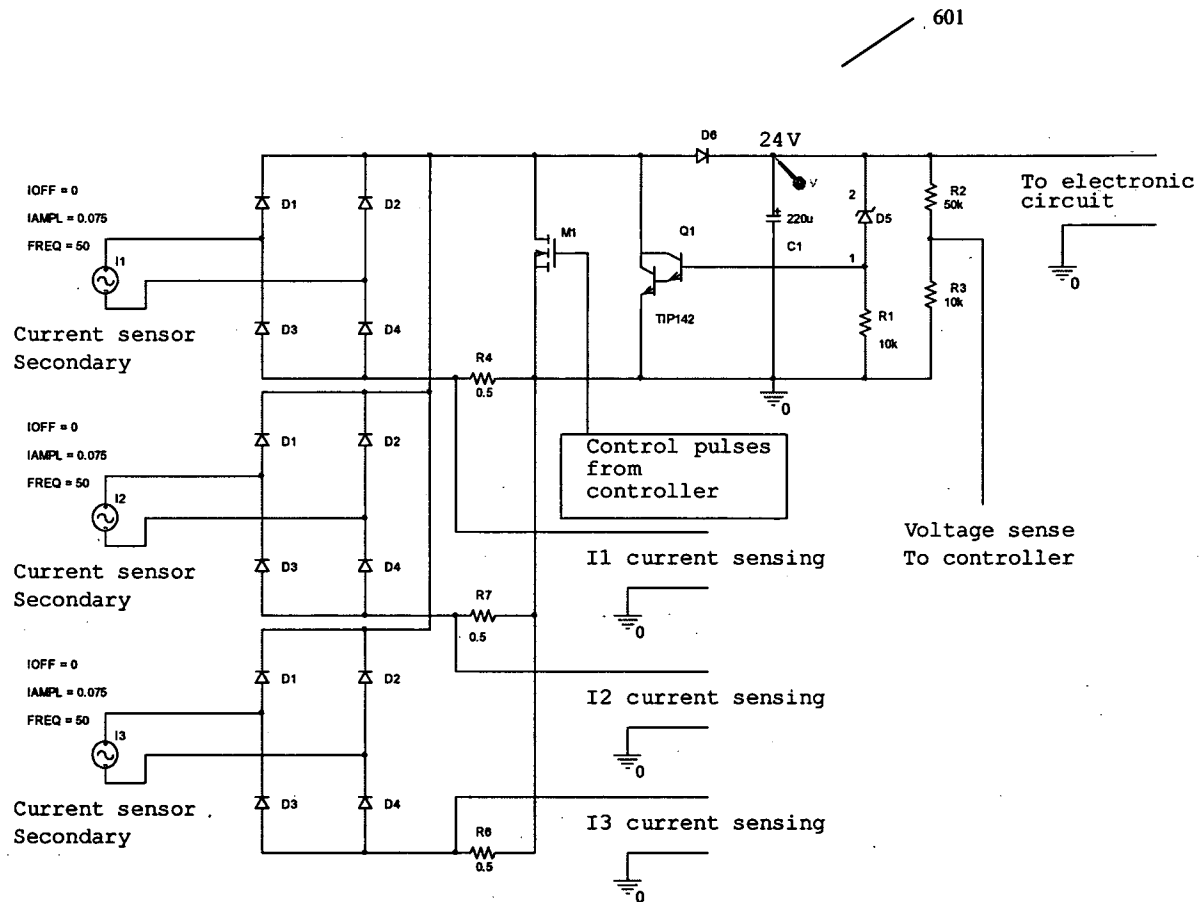
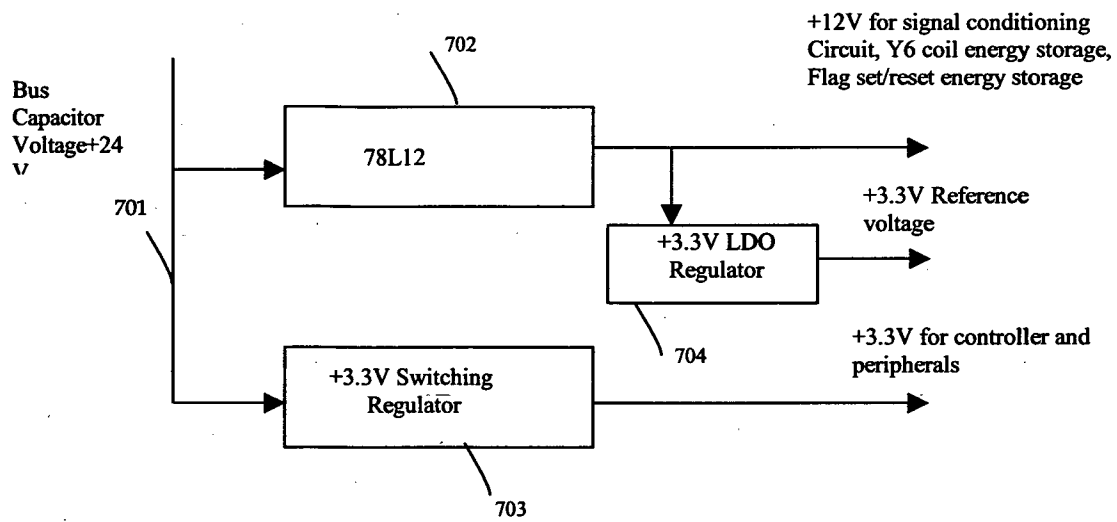


FIGURE: 6

**FIGURE: 7**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 2008/000439

A. CLASSIFICATION OF SUBJECT MATTER

IPC⁸: **H02H 3/08** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC⁸: H02H 3/08, H02H 3/08D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 32 23 687 A (LICENTIA PATENT-VERWALTUNGS-GmbH) 5 January 1984 (05.01.1984) <i>Whole document</i>	1
A	EP 0 469 207 A2 (FURNAS ELECTRIC COMPANY) 5 February 1992 (05.02.1992) <i>Abstract; claims; fig. 1</i>	1
A	US 7 304 828 B1 (VLADIMIR A. SHVARTSMAN) 4 December 2007 (04.12.2007) <i>Abstract; claims; fig. 1,2,3</i>	1

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search
19 June 2008 (19.06.2008)Date of mailing of the international search report
20 October 2008 (20.10.2008)Name and mailing address of the ISA/ AT
Austrian Patent Office
Dresdner Straße 87, A-1200 ViennaAuthorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 2008/000439

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 7 016 174 B2 (J.J. DOUGHERTY) 21 March 2006 (21.03.2006) <i>Abstract; claims; fig. 2</i>	1
A	-- US 2006/007627 A1 (L.M. LEWIS) 12 January 2006 (12.01.2006) <i>Abstract; claims; fig. 1,2</i>	1
A	-- US 6 459 557 B1 (S.T. HAENSGEN et al.) 1 October 2002 (01.10.2002) <i>Abstract; claims; fig. 4</i>	1
A	-- CN 1738125 A (LANZHOU DACHENG AUTOMATION ENG) 22 February 2006 (22.02.2006) (abstract) [online] [retrieved on: 17.06.2008] Retrieved from EPODOC Database <i>Abstract</i>	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/IB 2008/000439

Patent document cited in search report			Publication date	Patent family member(s)			Publication date
DE	A	3223687		DE	A1	3223687	1984-01-05
EP	A	0469207		JP	A	4229012	1992-08-18
				CA	A1	2026401	1992-02-03
				ES	T3	2066146T	1995-03-01
				EP	A2	0469207	1992-02-05
				DE	T2	69013683T	1995-03-02
				US	A	5179495	1993-01-12
US	A	7304828		US	B1	7304828	2007-12-04
US	A	7016174		US	A1	2003107860	2003-06-12
				EP	A2	1111752	2001-06-27
				CN	A	1306329	2001-08-01
				US	B1	6545849	2003-04-08
US	A	2006007627		US	A1	2006007627	2006-01-12