

**“ELECTRONIC SYSTEM AND METHOD FOR CONTROL, PROTECTION,
COMMUNICATION AND ENERGY SAVING FOR REFRIGERATION EQUIPMENT”**

FIELD OF INVENTION

The present invention relates to an integrated electronic system for providing control, protection, communication, and energy saving in refrigeration equipment, which is preferably, but not exclusively, used in refrigerators, freezers, refrigerated gondolas, refrigerated counters and other refrigeration equipment. The invention relates to a plurality of electrical and thermal sensors and actuators of the refrigeration equipment with the aim of controlling its internal temperature according to pre-programmed conditions, performing defrosting, protecting all electrical devices, saving electrical energy through a specific algorithm, and enabling communication of said equipment with others or with a monitoring center. The present invention has a modular and reprogrammable platform, so that it can be configured for different applications and situations.

DESCRIPTION OF THE STATE OF THE ART

As is well known from prior art, refrigeration equipment has several embedded electromechanical devices, such as: hermetic compressor, fans, valves, heating elements, thermostats, switches, lamps, temperature sensors, among others, interconnected to the refrigeration circuit which has an evaporator, condenser, refrigerant gas, filter, capillary tube, among others, all necessary for the perfect functioning of the equipment.

Temperature control within the refrigeration chamber (hereinafter referred to simply as the cabinet) is generally performed by an electromechanical or electronic thermostat which, through the control technique known as ON-OFF, activates the compressor whenever the temperature is at the upper limit of a given range and deactivates it when it is at the lower limit. Considering the products inside the cabinet, this is an inefficient control technique, as the temperature variation tends to be large and the response to thermal load transients tends to be slow. Furthermore, the condenser and evaporator fans are commonly linked to the thermostat and, consequently, to the compressor's operation. This strategy increases cabinet performance compared to those with fanless evaporators, but it does not provide the best energy efficiency because it does not allow the

evaporator fan to operate during the compressor shutdown period, which would allow for greater temperature homogeneity in the cabinet.

Another important point to consider is that the lack of intelligent evaporator defrosting systems leads manufacturers to use timers connected to electrical resistors that perform periodic defrosting cycles, since the ice accumulated in this part acts as thermal insulation, hindering heat exchange and, consequently, the efficiency of the system. This procedure is optimized by taking into account factors that contribute to ice formation, such as the frequency of door opening and the time it remains open, air humidity, outside temperature, among others, thus contributing to energy savings and food preservation, since during defrosting cycles there is an increase in the internal temperature of the cabinet.

Other electrical devices, such as lamps and anti-condensation resistors, consume more electrical energy in a cabinet without an intelligent control system, as they remain switched on throughout the cabinet's operating time.

Regarding system protection, it is known in current art that during a fault condition the compressor is switched off by the action of a bimetallic type thermal protector. However, the other electrical devices inside the cabinet are usually not protected, which increases the occurrence of failures and the magnitude of the damage. The use of more sophisticated resources is necessary to avoid damage to the cabinet due to electrical disturbances, or even malfunctioning cabinet operation.

Newer electronic controllers for refrigeration equipment incorporate multiple levels of "intelligence" in order to perform more sophisticated logical functions. Invariably, these controllers use microcontrollers to run control software and protection algorithms, as described in patents: US 5,808,441, US 6,427,772, US 6,745,581 and US 7,089,088, which address the control of various electrical devices and sensors in a predefined way. Brazilian patent application PI 0505623-3 reports an invention for remote communication with refrigeration equipment for technical assistance purposes, and PI 0705268-5 addresses the control of one or more refrigeration equipment devices, energy saving techniques, and system protection. US patents 5,806,321 and

US2006/0218946 A1 explore different approaches to defrosting, both seeking energy savings. US patent 5,918,474 specifically describes the operation of condenser and evaporator fans, also aiming at energy savings. US patent 5,209,076 refers to fault detection and compressor shutdown through specific logic. Furthermore, US patents 2007/0012054 A1 and US 7,228,693 consider the refrigeration system from the point of view of variable cooling capacity, also seeking energy savings.

Even considering the wide variety of electro-electronic systems for controlling refrigeration systems (hereinafter referred to simply as controllers), current techniques have several shortcomings that the present invention aims to solve, such as: increasing the flexibility of the controller's hardware and software, allowing it to be adjusted to meet different applications and situations, including the use of different electrical devices, sensors, and input/output (I/O) resources; incorporating an integrated system for simultaneous electrical, thermal, and mechanical protection; using a robust and high-performance algorithm to save electrical energy; increasing the flexibility and communication capacity of the controller, using a modem with GPRS (*General Packet Radio Service*) technology with a SIM (*Subscriber Identity Module*) type card, allowing remote access to the equipment via the internet, or through a local area network, connecting several cabinets to each other and/or to a monitoring center.

OBJECTS OF THE INVENTION

Therefore, the purpose of the present invention is to provide an integrated and flexible electronic system for controlling, protecting, communicating, and saving energy in refrigeration equipment, which is, in a preferred but not mandatory embodiment, used in refrigerators, freezers, refrigerated gondolas, refrigerated counters, and other refrigeration equipment. The invention has pre-programmed conditions to perform defrosting, protect all electrical devices, and enable communication between refrigeration equipment.

In line with the first objective, a second objective is to provide a method that includes an "energy saving" algorithm. This method takes into account several equipment parameters such as: frequency of cabinet door opening and time spent in this condition, cabinet idle time, internal

temperature of the cabinet, evaporator and condenser, operating hours of the establishment where the refrigerator is installed, among others.

BRIEF DESCRIPTION OF THE INVENTION

The objects of the present invention are achieved through an intelligent electro-electronic system (1) applied to the control, protection, communication and energy saving of refrigerators, containing one or more cabinets (refrigeration chambers), having at least one controller (1) equipped with a digital microprocessor that executes control programs to control and protect all components of the equipment, in addition to saving electrical energy through the execution of an algorithm that takes into account the frequency of door opening and time spent in this condition, the activation of the condenser and evaporator fans, regardless of the compressor's operating state, the activation of the anti-condensation and condenser defrosting resistors, business days and hours. The controller (1) has two configurations, called "BASIC" and "FULL". In "FULL" mode, it is coupled to a wireless modem (GPRS, for example) to communicate with a control center that adjusts the equipment's operating conditions according to its demand, and in "BASIC" mode, the controller (1) operates independently, but can be connected to a local area network which allows the exchange of information between cabinets and/or with a monitoring center.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1: Block diagram of the controller.

Figure 2: Behavior of the internal temperature of the cabinet for the "BASIC" mode, with the energy saver active.

Figure 3: Block diagram of the energy saver in "BASIC" mode.

Figure 4: Wireless communication network using mobile phone network technology.

Figure 5: The power consumption behavior of the cabinet and its internal temperature for "FULL" mode, with the power saver active.

Figure 6: Block diagram of the energy saver in "FULL" mode.

Figure 7: Example of the defrost function operation.

Figure 8: Multi-compressor system connected to a local area network.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will be described in detail by means of Figures 1 to 8, which illustrate some preferred, but not mandatory, embodiments for implementing the present invention.

Figure 1 illustrates the block diagram of the controller (1) with all the circuits needed to
5 implement it in refrigeration equipment, including all the electrical loads of the cabinet. The controller (1) is connected to the electrical network (2) and has interfaces with the refrigeration system via the hermetic compressor (3), evaporator fan (4), condenser fan (5), lamps (6), door switch (7), condenser temperature sensor (8), evaporator temperature sensor (9), cabinet temperature sensor (10), defrost resistor (11) and anti-condensation resistor (12). The other
10 components of the equipment that are part of the refrigeration circuit, such as the evaporator, condenser, filter, and capillary tube, are not shown in the figures.

In the design illustrated in Figure 1, the controller (1) consists of a printed circuit board (PCI), a line filter (20) connected to the mains power supply to filter conducted electromagnetic interference, a switched-mode power supply (21) that converts alternating current (AC) from the
15 mains power supply to direct current (DC) to power circuits that use low DC voltage, a circuit (22) that checks the AC mains voltage and sends the signal to an analog circuit (23) that converts its level and transmits to the microcontroller (MCU) (26) a sample of the magnitude of the AC voltage and the instant of its zero crossing, a set of TRIACs (27) controlled by the MCU (26) responsible for switching on and off all electrical loads in the equipment, an AC current sensor (24) that
20 measures the compressor current and sends the signal to an analog circuit (25) that performs the level conversion and sends to the MCU (26) a sample of the magnitude of the AC current and the instant of its zero crossing, by a circuit (28) that monitors the opening of the cabinet door by means of the key (7), by three identical analog circuits (29), which are configured as inputs for one or more temperature sensors (NTC type thermistors, for example) (8), (9) and (10) and/or general
25 purpose analog inputs. The controller board (1) has several digital communication features between devices. The first of these is a serial driver (30) suitable for connecting the controller board (1) to other digital devices via a human-machine interface (HMI) (13), using a serial cable (14). The

second communication resource is an RS-485 type driver (33) used to build a local area network with up to 32 nodes, connecting several controllers of a multi-compressor refrigeration equipment, or several different refrigeration equipment, where each node of the network has a controller (1) or other communication device that supports the RS-485 standard (33). An important feature of the present invention is its wireless communication capability, made by means of, but not limited to, a wireless modem with GPRS (*General Packet Radio Service*) technology (31), for example, but not limited to this, and a SIM (*Subscriber Identity Module*) type card (32), analogous to those used in cellular phones with GSM (*Global System for Mobile Communications*) technology, containing an antenna (17) mounted outside the controller housing, the designation "FULL" being used for such designation. In an alternative embodiment, the present invention has an HMI (13) with a USB (*Universal Serial Bus*) port that allows the controller to be connected to a personal computer (PC) (16), or other device that supports the USB standard, for local access in the system. The term "BASIC" refers to the controller in the absence of a wireless communication interface.

The present invention has the ability to control the electrical loads (on/off) commonly found in commercial refrigeration equipment, such as: defrost resistor (11), anti-condensation resistor (12), evaporator fan (4), condenser fan (5), lamps (6) and, naturally, the hermetic compressor (3). One of the advantages of the present invention is the flexibility of the hardware to adapt to the set of TRIACs (27), in order to meet different loads, with different power classes, the flexibility in adapting the analog inputs (29), to meet different sensors and also the flexibility in configuring the communication system, as well as the software, to meet different demands.

The MCU (26) manages all cabinet operations by running the software installed in its memory, protecting the equipment and reporting faults and abnormal operating conditions, such as: over and under voltage of the electrical network, over and under frequency of the electrical network, compressor overcurrent, compressor overload, locked compressor rotor, condenser overheating, evaporator overheating, cabinet over and under temperature and temperature sensor failure (short circuit or open circuit).

The software installed in the MCU (26) runs a digital controller for adjusting the internal temperature of the cabinet. This temperature adjustment (hereinafter referred to as the temperature setpoint) is made via the HMI (13), and/or by a mobile device connected to the HMI's USB port (13), and/or by a standard RS-485 local area network, and/or remotely using a wireless modem. In a particular embodiment of the present invention, the temperature setpoint is calculated by the controller (1) using an "energy saving" algorithm which will be described subsequently.

The present invention has two "energy saving" algorithms: one for "BASIC" mode and another for "FULL" mode, exemplified by the temperature behavior of a cabinet in Figures 2 and 4, respectively, as a function of time.

Figure 2 illustrates, through a graph, the performance of the "energy saving" algorithm on the cabinet temperature behavior as a function of time, in "BASIC" mode, taking into account the frequency of door openings and the time the door remains open. The objective is to evaluate cabinet idle periods, evidenced mainly by long periods without the door being opened, and thus automatically increase the temperature setpoint, so that the time between consecutive compressor (3) activations is increased, thereby reducing energy consumption. This strategy is represented by graph (50), which shows a hypothetical temperature variation inside the cabinet, and by graph (60), which shows a hypothetical behavior of the cabinet door condition (0=open or 1=closed).

When the cabinet is switched on for the first time (or after a long period of being switched off), the MCU (26) reads the temperature setpoint, previously programmed by the user, and compares it with the actual value provided by the sensor (10). At this moment, a software counter is started, whose function is to block the activation of the electrical "energy saving" mode under unfavorable conditions, taking into account the time duration defined as "td1" (52). The initial value assigned to the counter is a function of the estimated minimum time for the first temperature drop (hereinafter referred to as "*pull down*"), usually the value of "td1" is set in the range of one to three hours. Cabinet temperature control is achieved by acting on the compressor (3) using the on/off technique with a dead band (ΔT). During the time count "td1" (52) the door behavior is irrelevant (61); after the time count "td1" (52), the cabinet reference temperature is automatically changed as

a function of the door behavior, exemplified by the graph (60) in Figure 2. Figure 2 exemplifies the variation of the cabinet temperature (51), whose initial adjustment is made by the user, called "T2" (53). At the end of the time count "td1" (52), at the instant "t1" (54), the system is able to save energy and, with this, the controller (1) starts monitoring the door through the circuit (28). If this is opened rarely and/or for short periods of time (62), the "energy saving mode" is activated and, from this moment on, the temperature increases at a pre-set rate, to pre-programmed values. For example, at time "t2" (55) the cabinet reaches temperature "T3" (56) and, after a minimum time remaining at this temperature, reaches temperature "T4" (57), remaining in this condition until the "power saving" mode is automatically disabled due to a long period of opening the cabinet door (70), for example, or another pre-established condition. Thus, at time "t4" (59), the "energy saving" function is disabled. In this case, the reference temperature automatically returns to the value "T2" (53), set by the user. A new time count "td1" (52) is started and, as soon as its value reaches the unlock level, it resumes the ramp until it reaches the maximum savings value, repeating the cycle. This function can be locked or unlocked indefinitely depending on how the cabinet is used.

For clarity, Figure 3 illustrates the simplified block diagram of the energy-saving algorithm in "BASIC" mode.

Figure 4 illustrates how wireless modem communication works. The cabinets (70) distributed in the field communicate via wireless modem (31) with the radio base stations (RBS) (71) belonging to the mobile telephone network (72). A server (73) from the mobile phone operator switches the information from the cabinet (70) to the internet (74) and a data center (75) stores it in a database (76), allowing the user/client connected to the internet (74), through their personal computer (77), to access a website to receive and/or send information to the cabinets.

Figure 5 illustrates, through a graph, the performance of the "energy saving" algorithm on the internal temperature of a bottle refrigerator cabinet as a function of time, in "FULL" mode. In a preferred, but not mandatory, conception, the technique used is based on a program transmitted from a data center (75) to the offices (70), once a week, on a pre-established day. Therefore, each

cabinet receives its weekly work profile which consists of two “types of day”: “working day” (81) and “day off” (86), for equipment in commercial establishments that are open or closed, respectively. In this conception, the “working day” (81) is divided into three periods: “pull down” (temperature decrease) (83), “working time” (normal operation) (84) and “stand-by” (85). On 5 “weekdays” (81), the times at which the point of sale is open and closed are defined for each office (70), taking into account holidays for the different locations. Graph (80) in Figure 4 illustrates the energy consumed by the refrigerators while graph (90) shows the variation in internal cabinet temperature (70), considering the transition from a “working day” (81) to a “rest day” (86) (from Saturday to Sunday, for example). Curves (91) and (92) of graph (90) are, respectively, the 10 temperature of sensor (10) and the average temperature of the liquid in the bottles inside the cabinet. According to the technique discussed, the cabinet should contain the bottles at the appropriate temperature for sale (-5 °C, for example) at 8:00 AM on the first business day. Since the equipment remains in "stand-by" mode after 6:00 PM, for example, the average temperature of the bottles rises to +5°C under these conditions. With this, the controller performs anticipatory 15 actions and initiates the “pull-down” (83) so that, at the moment the commercial establishment opens, the bottles are at the appropriate temperature. At 8:00 am the establishment enters “working time” (84), remaining in this state until 6:00 pm of the same day, when the office returns to the “stand-by” state (85) after the establishment closes. With this, the controller completely shuts off the compressor, which is only switched on after the cabinet temperature reaches a predefined upper 20 limit, then re-entering the on/off cycles to maintain the cabinet at +5 °C, for example, which is the “stand-by” temperature (87). It can be observed in the graph (80) periods of idleness, as well as different compressor on/off cycles between “working time” (84) and “stand-by” (85/87). These two conditions provide a significant reduction in electricity consumption, which is a function of the usage profile programming.

25 For clarity, Figure 6 illustrates the simplified block diagram of the energy-saving algorithm in "FULL" mode.

According to another aspect of the present invention, the software installed in the MCU (26) controls the defrosting of the evaporator, since the accumulation of ice in this part acts as a thermal insulator, reducing the efficiency of the refrigeration system and, consequently, increasing the consumption of electrical energy. In one embodiment of the present invention, the defrosting process will be described with reference to graph (100) of Figure 7. In the present invention, the defrosting operations occur automatically whenever ice forms in the condenser, without the need for the user to adjust it.

When the cabinet is turned on for the first time (or after a long period of being turned off), the counting of a control software variable called “t_dg”, from graph (100), which represents the time duration until the next defrost event, starts from its maximum value “t_dg_max” (101), decaying over time at a constant rate (102) and, additionally, with each door opening event, “t_dg” is subtracted from a value, exemplified in graph (100) by instants (103) and (104). When the lower limit “t_dg_min” (105) is reached, the defrosting procedure starts by activating the resistance (11). However, for this event to occur, two conditions must occur simultaneously: the compressor (3) must be off and “t_dg” must have a minimum value, as previously defined. A limiter monitors the maximum time the heating element is on, but the heating element on time count may be interrupted if the evaporator temperature sensor (9) shows a temperature equal to or greater than a preset limit. During defrosting, the compressor (3) is blocked from operating, and is only released at the end of this event. The variable “t_dg” returns to its original value at the end of this event.

Additionally, the MCU (26) of the controller (1) executes a control program that performs the following operations: compressor start and stop control (3) through the analysis of pre-established conditions, such as: mains voltage within the operating range, imbalances between suction and discharge pressures and the existence of electrical faults. A control algorithm independently commands the evaporator fan (4) and the condenser fan (5), since it is well known in the art that the optimized operation of these devices influences the efficiency of the refrigeration system and, consequently, the energy consumption. Monitoring the door condition, via the switch (7), provides information for the “energy saving” algorithm routine. Another task of the controller (1) is to

command the activation of the anti-condensation resistor (12), usually installed on the door or side of the cabinet, to prevent water condensation on the outside, due to deficiencies in thermal insulation. Furthermore, the controller (1) turns off the cabinet lighting (6) when the system is in “stand-by” mode.

5 Figure 8 illustrates the communication between several controllers (1), connected in a bus-type local area network configuration (110), with up to 32 nodes, RS-485 standard (33). Each node consists of a controller (1) and a refrigeration unit (112), comprising a system of multiple compressors (113). In a further conception, a computer (115), with an isolated RS-485 network
10 adapter (114), is connected to the network to act as the network master and/or “gateway” (intermediate machine intended to interconnect networks), to a higher hierarchical level network. This network structure is useful when you want to manage an entire plant, for example, the refrigeration system of a large supermarket, consisting of a series of freezers, displays, refrigerated islands, refrigerated gondolas, cold rooms, refrigerated counters, among others.

 In another conception, the controller (1) is connected to an HMI (13) in the cabinet via a serial
15 communication cable (14), having a display that allows the visualization of parameters such as temperature and fault messages. This HMI (13) has a USB communication port that allows connection of a computer (16) via a USB cable (15), thus enabling monitoring and adjusting the equipment locally.

 According to the teachings already described in the present invention, the MCU (26) executes
20 electrical, thermal and mechanical protection algorithms that protect the refrigeration equipment against extreme operating conditions, contributing to increasing its service life. The parameters monitored to perform equipment protection are as follows: under and over voltage of the electrical network, under and over frequency of the electrical network, compressor overcurrent, under and over temperature in the cabinet (70), over temperature for defrosting the evaporator, over
25 temperature in the condenser, failure and/or inversion of the temperature sensors (8), (9) and (10), compressor thermal overload (3), under and over suction and/or discharge pressures of the compressor (3) (when using sensors for this purpose), locked compressor rotor (3). All protection

limits are defined by the user according to the application and alarms are transmitted to the HMI (13) and/or to a remote device.

The present invention proposes a controller (1) for the refrigeration system based on a flexible hardware and software platform concept, i.e., electronic circuits and programs specially designed to allow different configurations depending on the final application, implying several competitive advantages for the aforementioned controller (1).

The examples and descriptions mentioned in the present invention are merely illustrative and should not be understood as limiting in any way, within the scope of the invention, according to the claims.

10 **CONSTRUCTION VARIANTS**

In an alternative, but not mandatory, conception, the present invention consists of an HMI (13), composed of at least one other PCI, with at least one microcontroller, which executes a second control program, a point-to-point electronic communication circuit, which allows communication between the HMI (13) and the controller (1) (connected by a serial communication cable (14)), a user interface system, implemented by a plurality of “tact” type switches, but not limited to these, for the selection of different operating options, a user interface system, implemented by a plurality of displays and/or light emitting diodes (LEDs), to inform the user of the different operating states, as well as to indicate the cabinet temperature and fault alarms. This HMI (13) has a USB type communication port, but is not limited to this, which allows the connection of a computer (16) via a USB cable (15), thus enabling monitoring and adjusting the equipment locally.

In another additional aspect, the “energy saving” algorithm executes a logic of periodic temperature reduction if the cabinet is operating at a high temperature setpoint “T4” (57) for a long period.

CLAIMS

1. Electronic system for control, protection, communication and energy saving for refrigeration equipment, characterized by having an electronic module, said controller (1), with at least one printed circuit board (PCB), containing a digital microcontroller (MCU) (26), with a control
5 program installed in its memory, a circuit for measuring alternating current (24) and voltage (22), an analog conditioning circuit for measuring alternating current (25) and voltage (23), a circuit for monitoring the opening of the cabinet door (28), an analog circuit for interfacing with the cabinet temperature sensors (29), a circuit with static power switches (27), solid-state and/or electromechanical relay type, a wireless communication system (31), with an antenna (17), a
10 standard RS-485 electronic circuit (33), an electronic circuit for communication (30) with a human-machine interface (HMI) (13) and a system with multiple electrical connectors for connecting the control module (1) to the system. refrigeration.

2. Electronic system for control, protection, communication and energy saving for refrigeration equipment, according to claim 1, characterized by having at least one HMI (13), consisting of a
15 PCB, with a microcontroller, which executes a control program, an electronic circuit for point-to-point connection between the HMI (13) and the controller (1), another electronic circuit for point-to-point communication between the HMI (13) and the personal computer (PC) (16) via USB interface, a multiplicity of “tact” type switches, a multiplicity of displays and/or light emitting diodes (LEDs) and audible alarms.

20 3. Electronic system for control, protection, communication and energy saving for refrigeration equipment, according to claim 1, characterized by having an electronic module for communication via wireless modem, with GPRS technology (31): or higher (EDGE or 3G for example).

4. Electronic system for control, protection, communication and energy saving for refrigeration equipment, according to claim 3, characterized by having an electronic module for communication
25 via wireless modem through the mobile telephone network, wherein each controller (1) uses a SIM card (32).

5. Electronic system for control, protection, communication and energy saving for refrigeration equipment, according to claim 1, characterized by having a wireless communication system of the IEEE 802.11 standard *wifi* type.

6. Electronic system for control, protection, communication and energy saving for refrigeration equipment, according to claims 3 and 5, characterized by sending and/or receiving data from the equipment via the internet.

7. Electronic system for control, protection, communication and energy saving for refrigeration equipment, according to claim 1, characterized by having a communication protocol via RS-485 for a local network.

8. Method for controlling, protecting, communicating and saving energy in refrigeration equipment, characterized by comprising a program installed in the MCU (26), developed to control all operations of the refrigeration equipment, involving the control of the hermetic compressor (3), defrost resistor (11), anti-condensation resistor (12), evaporator fan (4), condenser fan (5), lighting (6), reading of temperature sensors (8), (9), (10) and door status (7), control of electrical energy consumption and a multiplicity of communication interfaces (30), (31) and (33).

9. A method for controlling, protecting, communicating, and saving energy in refrigeration equipment, according to claim 8, characterized by executing an electrical, mechanical, and thermal protection algorithm for the refrigerator through digital measurement and processing of voltage, current, and frequency parameters of the electrical network, internal temperature of the cabinet, evaporator, and condenser, over-temperature or locking of the compressor rotor, and cabinet door condition.

10. A method for controlling, protecting, communicating, and saving energy in refrigeration equipment, according to claim 8, characterized by executing an "energy saving" algorithm through the digital measurement and processing of parameters such as the frequency of cabinet door openings and the time spent in this condition, cabinet idle time, internal temperature of the cabinet, evaporator, and condenser, and the operating hours of the establishment where the refrigerator is installed.

11. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 10, characterized by an “energy saving” algorithm in the “BASIC” version, without a wireless communication module, which initially checks the cabinet “idle” periods, evidenced mainly by long absences of door opening and thus, to automatically increase the cabinet temperature setpoint, such that under a given thermal load condition, increasing the temperature setting means increasing the time between two consecutive activations of the compressor (3) and fans (4) and (5), therefore reducing energy consumption, as shown in Figure 3.

12. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 11, characterized by automatically increasing the reference temperature of the cabinet (10) when the minimum dwell time at said temperature, monitored by the variable “td1” (52), as selected by the user, has expired.

13. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 12, characterized by providing an initial value to the variable "td1" (52) as a function of the cabinet temperature, measured by the sensor (10) and an estimated minimum time for the first temperature drop (pull down).

14. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 13, characterized by monitoring the behavior of the cabinet door (10) to increase or decrease the variable "td1" (52) so that, during the "pull-down" time, if the door opens, "td1" (52) increases; once the "pull-down" time is over, this variable decreases with increasing time at a previously adjusted rate.

15. A method for controlling, protecting, communicating, and saving energy in refrigeration equipment, according to claim 14, characterized by automatically disabling the "power saving mode" whenever there are excessive and/or extensive openings of the cabinet door, forcing the variable "td1" to decrease to its minimum value and, in this case, the temperature setpoint automatically returns to the value previously set by the user and the variable "td1" is readjusted according to its initial value.

16. A method for controlling, protecting, communicating, and saving energy in refrigeration equipment, according to claim 14, characterized by automatically enabling the "electrical energy saving mode" as soon as a new time count occurs, the duration of which coincides with the value of the variable "td1", and after this event, the setpoint value of the refrigerated compartment temperature of the cabinet resumes the ramp until it reaches the maximum energy saving value, and the activation and deactivation of this function can occur indefinitely due to the use of the cabinet.

17. A method for controlling, protecting, communicating, and saving energy in refrigeration equipment, according to claim 16, characterized by executing the logic of periodically lowering the temperature of the refrigerated compartment of the cabinet if it is operating at the maximum temperature setpoint for too long.

18. Method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 10, characterized by an "energy saving" algorithm in the "FULL" version, with a wireless communication module aimed at transmitting the programming from the data center to the cabinets (70), on a pre-established day, aiming to increase the temperature of the cabinet (70) whenever the point of sale is closed or outside of service hours, as shown in Figure 6.

19. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 18, characterized by sending to the cabinets (70) their respective weekly operating schedules, based on the application and working time where the cabinets are installed.

20. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 19, characterized by considering the weekly schedule consisting of two "types of day": "work day" (81) and "rest day" (86), where the "work day" is divided into three periods: "pull down" (83), "work time" (84) and "stand-by" (85), wherein for each "work day" the start of the point of sale operation (start of work time) (82) is defined and, after this time, the work time (84) itself.

21. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 20, characterized by providing a routine to save energy, in which every time the cabinet (10) is operating on a “working day” (81) and before the “start of working time” (82), the algorithm performs a temperature reduction called “pull-down” (83) to the setpoint defined by the user, such that at the “start of working time” (82) the refrigerated product will be at the ideal temperature for sale, and during the “pull-down” (83) the cabinet lighting is deactivated and the anti-condensation resistor is activated.

22. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 20, characterized by providing a routine to save energy so that, every time the cabinet is operating on a “working day” (81) and during the “working hours” (84), the algorithm performs the internal temperature control of the cabinet to maintain it at the setpoint defined by the user, by means of a deadband (ΔT) on/off technique, wherein during the “working time” (84) the cabinet lighting and the anti-condensation resistor are activated and the defrost time counter remains enabled.

23. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 20, characterized by providing a routine to save energy, whereby every time the cabinet (10) is operating on a “working day” (81) and after the “working hours” (84), the equipment enters “stand-by” (85), remaining in this state until a new “pull-down” (83), wherein, during the “stand-by” (85), the setpoint of the internal temperature of the cabinet is increased and both the cabinet lighting, the defrosting procedure and the anti-condensation resistance are deactivated.

24. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 20, characterized by providing a routine to save energy, according to which every time the cabinet is in operation on a “rest day” (86), the algorithm will keep the cabinet (10) in “stand-by” (87) all day, the setpoint of the cabinet’s internal temperature is increased and both the cabinet lighting, the defrosting procedure and the anti-condensation resistor are deactivated.

25. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 8, characterized by an integrated control system that controls all the electrical loads of the refrigerator, through data from sensors (7), (8), (9), (10), (22) and (24) and communication interfaces (30), (31) and (33).

5 26. A method for controlling, protecting, communicating, and saving energy in refrigeration equipment, according to claim 8, characterized by executing an algorithm for defrosting the evaporator.

10 27. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 26, characterized by having a defrost function, containing a variable called "Dg_b", but not limited to this, starting with the value zero and, in a second moment, incremented at a constant rate independent of the opening of the cabinet door, or the operation of the compressor (3) and simultaneously another variable called "t_dg", but not limited to this, which represents the duration of time until the next defrost event, is started with a previously chosen maximum value (101), decreasing over time (102) and, additionally, in each door opening event, 15 "t_dg" is subtracted from a fixed value (103) and (104) and defrosting is initiated when the lower limit assigned to the variable "t_dg" is reached (105).

20 28. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 27, characterized by activating the evaporator defrosting method when two simultaneous conditions occur: compressor (3) off and the variable "t_dg" has a minimum value.

AMENDED CLAIMS

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1. Electronic system for control, protection, communication and energy saving for refrigeration equipment, characterized by having an electronic module, said controller (1), with at least one
5 printed circuit board (PCB), containing a digital microcontroller (MCU) (26), with a control program installed in its memory, a circuit for measuring alternating current (24) and voltage (22), an analog conditioning circuit for measuring alternating current (25) and voltage (23), a circuit for
10 monitoring the opening of the cabinet door (28), an analog circuit for interfacing with the cabinet temperature sensors (29), a circuit with static power switches (27), solid-state and/or electromechanical relay type, a wireless communication system (31), with an antenna (17), a
standard RS-485 electronic circuit (33), an electronic circuit for communication (30) with a human-machine interface (HMI) (13) and a system with multiple electrical connectors for connecting the
control module (1) to the system. refrigeration.

2. Electronic system for control, protection, communication and energy saving for refrigeration
15 equipment, according to claim 1, characterized by having at least one HMI (13), consisting of a PCB, with a microcontroller, which executes a control program, an electronic circuit for point-to-point connection between the HMI (13) and the controller (1), another electronic circuit for point-to-point communication between the HMI (13) and the personal computer (PC) (16) via USB
interface, a multiplicity of “tact” type switches, a multiplicity of displays and/or light emitting
20 diodes (LEDs) and audible alarms.

3. Electronic system for control, protection, communication and energy saving for refrigeration equipment, according to claim 1, characterized by having an electronic module for communication via wireless modem, with GPRS technology (31): or higher (EDGE or 3G for example).

4. Electronic system for control, protection, communication and energy saving for refrigeration
25 equipment, according to claim 3, characterized by having an electronic module for communication via wireless modem through the mobile telephone network, wherein each controller (1) uses a SIM card (32).

5. Electronic system for control, protection, communication and energy saving for refrigeration equipment, according to claim 1, characterized by having a wireless communication system of the IEEE 802.11 standard *wifi* type.

6. Electronic system for control, protection, communication and energy saving for refrigeration equipment, according to claims 3 and 5, characterized by sending and/or receiving data from the equipment via the internet.

7. Electronic system for control, protection, communication and energy saving for refrigeration equipment, according to claim 1, characterized by having a communication protocol via RS-485 for a local network.

8. Method for controlling, protecting, communicating and saving energy in refrigeration equipment, characterized by comprising a program installed in the MCU (26), developed to control all operations of the refrigeration equipment, involving the control of the hermetic compressor (3), defrost resistor (11), anti-condensation resistor (12), evaporator fan (4), condenser fan (5), lighting (6), reading of temperature sensors (8), (9), (10) and door status (7), control of electrical energy consumption and a multiplicity of communication interfaces (30), (31) and (33).

9. A method for controlling, protecting, communicating, and saving energy in refrigeration equipment, according to claim 8, characterized by executing an electrical, mechanical, and thermal protection algorithm for the refrigerator through digital measurement and processing of voltage, current, and frequency parameters of the electrical network, internal temperature of the cabinet, evaporator, and condenser, over-temperature or locking of the compressor rotor, and cabinet door condition.

10. A method for controlling, protecting, communicating, and saving energy in refrigeration equipment, according to claim 8, characterized by executing an "energy saving" algorithm through the digital measurement and processing of parameters such as the frequency of cabinet door openings and the time spent in this condition, cabinet idle time, internal temperature of the cabinet, evaporator, and condenser, and the operating hours of the establishment where the refrigerator is installed.

11. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 10, characterized by an “energy saving” algorithm in the “BASIC” version, without a wireless communication module, which initially checks the cabinet “idle” periods, evidenced mainly by long absences of door opening and thus, to automatically increase the cabinet temperature setpoint, such that under a given thermal load condition, increasing the temperature setting means increasing the time between two consecutive activations of the compressor (3) and fans (4) and (5), therefore reducing energy consumption, as shown in Figure 3.

12. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 11, characterized by automatically increasing the reference temperature of the cabinet (10) when the minimum dwell time at said temperature, monitored by the variable “td1” (52), as selected by the user, has expired.

13. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 12, characterized by providing an initial value to the variable "td1" (52) as a function of the cabinet temperature, measured by the sensor (10) and an estimated minimum time for the first temperature drop (pull down).

14. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 13, characterized by monitoring the behavior of the cabinet door (10) to increase or decrease the variable "td1" (52) so that, during the "pull-down" time, if the door opens, "td1" (52) increases; once the "pull-down" time is over, this variable decreases with increasing time at a previously adjusted rate.

15. A method for controlling, protecting, communicating, and saving energy in refrigeration equipment, according to claim 14, characterized by automatically disabling the "power saving mode" whenever there are excessive and/or extensive openings of the cabinet door, forcing the variable "td1" to decrease to its minimum value and, in this case, the temperature setpoint automatically returns to the value previously set by the user and the variable "td1" is readjusted according to its initial value.

16. A method for controlling, protecting, communicating, and saving energy in refrigeration equipment, according to claim 14, characterized by automatically enabling the "electrical energy saving mode" as soon as a new time count occurs, the duration of which coincides with the value of the variable "td1", and after this event, the setpoint value of the refrigerated compartment temperature of the cabinet resumes the ramp until it reaches the maximum energy saving value, and the activation and deactivation of this function can occur indefinitely due to the use of the cabinet.

17. A method for controlling, protecting, communicating, and saving energy in refrigeration equipment, according to claim 16, characterized by executing the logic of periodically lowering the temperature of the refrigerated compartment of the cabinet if it is operating at the maximum temperature setpoint for too long.

18. Method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 10, characterized by an "energy saving" algorithm in the "FULL" version, with a wireless communication module aimed at transmitting the programming from the data center to the cabinets (70), on a pre-established day, aiming to increase the temperature of the cabinet (70) whenever the point of sale is closed or outside of service hours, as shown in Figure 6.

19. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 18, characterized by sending to the cabinets (70) their respective weekly operating schedules, based on the application and working time where the cabinets are installed.

20. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 19, characterized by considering the weekly schedule consisting of two "types of day": "work day" (81) and "rest day" (86), where the "work day" is divided into three periods: "pull down" (83), "work time" (84) and "stand-by" (85), wherein for each "work day" the start of the point of sale operation (start of work time) (82) is defined and, after this time, the work time (84) itself.

21. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 20, characterized by providing a routine to save energy, in which every time the cabinet (10) is operating on a “working day” (81) and before the “start of working time” (82), the algorithm performs a temperature reduction called “pull-down” (83) to the setpoint defined by the user, such that at the “start of working time” (82) the refrigerated product will be at the ideal temperature for sale, and during the “pull-down” (83) the cabinet lighting is deactivated and the anti-condensation resistor is activated.

22. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 20, characterized by providing a routine to save energy so that, every time the cabinet is operating on a “working day” (81) and during the “working hours” (84), the algorithm performs the internal temperature control of the cabinet to maintain it at the setpoint defined by the user, by means of a deadband (ΔT) on/off technique, wherein during the “working time” (84) the cabinet lighting and the anti-condensation resistor are activated and the defrost time counter remains enabled.

23. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 20, characterized by providing a routine to save energy, whereby every time the cabinet (10) is operating on a “working day” (81) and after the “working hours” (84), the equipment enters “stand-by” (85), remaining in this state until a new “pull-down” (83), wherein, during the “stand-by” (85), the setpoint of the internal temperature of the cabinet is increased and both the cabinet lighting, the defrosting procedure and the anti-condensation resistance are deactivated.

24. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 20, characterized by providing a routine to save energy, according to which every time the cabinet is in operation on a “rest day” (86), the algorithm will keep the cabinet (10) in “stand-by” (87) all day, the setpoint of the cabinet’s internal temperature is increased and both the cabinet lighting, the defrosting procedure and the anti-condensation resistor are deactivated.

25. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 8, characterized by an integrated control system that controls all the electrical loads of the refrigerator, through data from sensors (7), (8), (9), (10), (22) and (24) and communication interfaces (30), (31) and (33).

5 26. A method for controlling, protecting, communicating, and saving energy in refrigeration equipment, according to claim 8, characterized by executing an algorithm for defrosting the evaporator.

10 27. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 26, characterized by having a defrost function, wherein when the cabinet is turned on for the first time or after an elongated period switched off, it starts counting a variable of the control software called "t_dg" of chart (100) representing the duration of time until the next defrosting event , and it starts from the maximum value "t_dg_max" (101), decreasing over time at a constant rate (102) and, additionally, in each door opening event, "t_dg" is subtracted from a value exemplified in chart (100) by time (103) and (104) and in that when the lower limit
15 "t_dg_min" (105) is reached the defrosting procedure starts by actuating the resistance (11).

28. A method for controlling, protecting, communicating and saving energy in refrigeration equipment, according to claim 27, characterized by activating the evaporator defrosting method when two simultaneous conditions occur: compressor (3) off and the variable "t_dg" has a minimum value.

ABSTRACT

The present invention relates to an integrated electronic system (1) for providing control, protection, communication, and energy saving in refrigeration equipment, which is preferably, but not exclusively, used in refrigerators, freezers, refrigerated gondolas, refrigerated counters and other refrigeration equipment. The invention is connected to a plurality of electrical and thermal sensors and actuators of the refrigeration equipment in order to control its internal temperature according to pre-programmed conditions, perform defrosting, protect all electrical devices, save electrical energy through a specific algorithm, and enable its remote control and monitoring. The present invention has a modular and reprogrammable platform, so that it can be configured for different applications and situations.

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FIGURES

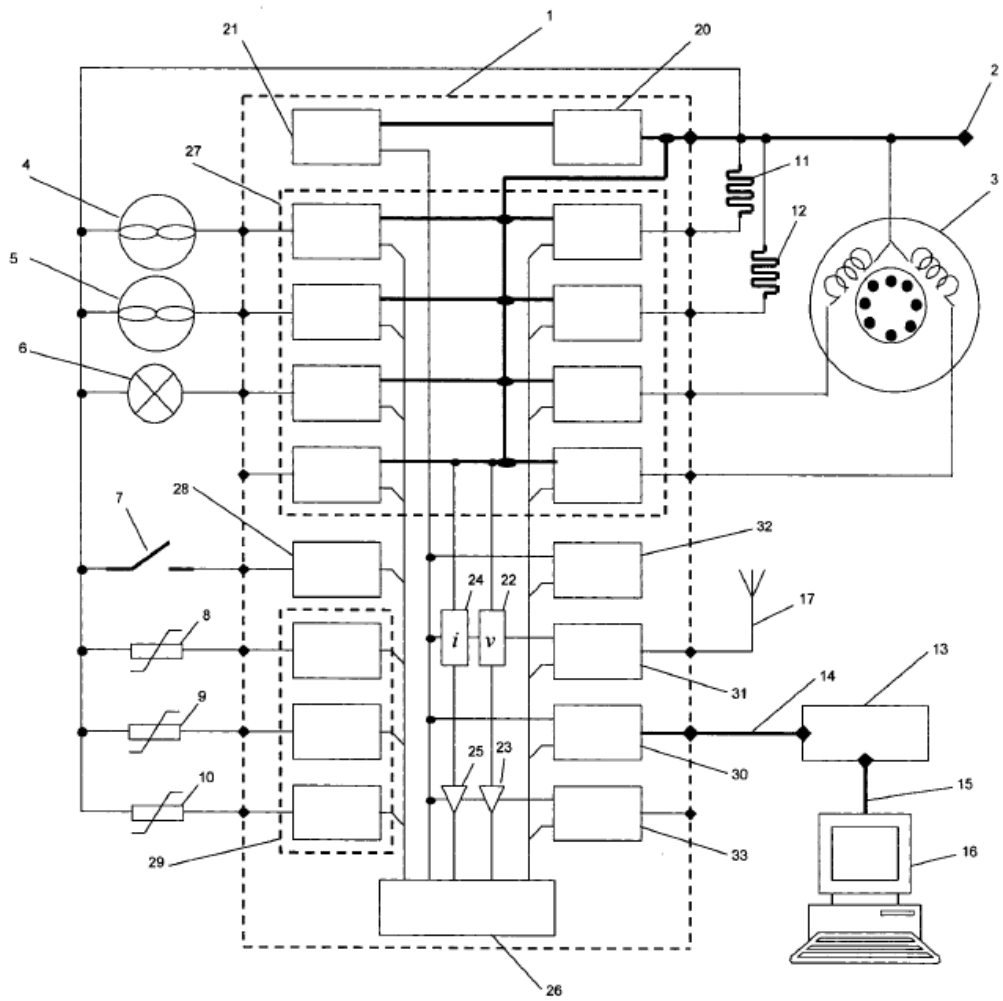


FIG. 1

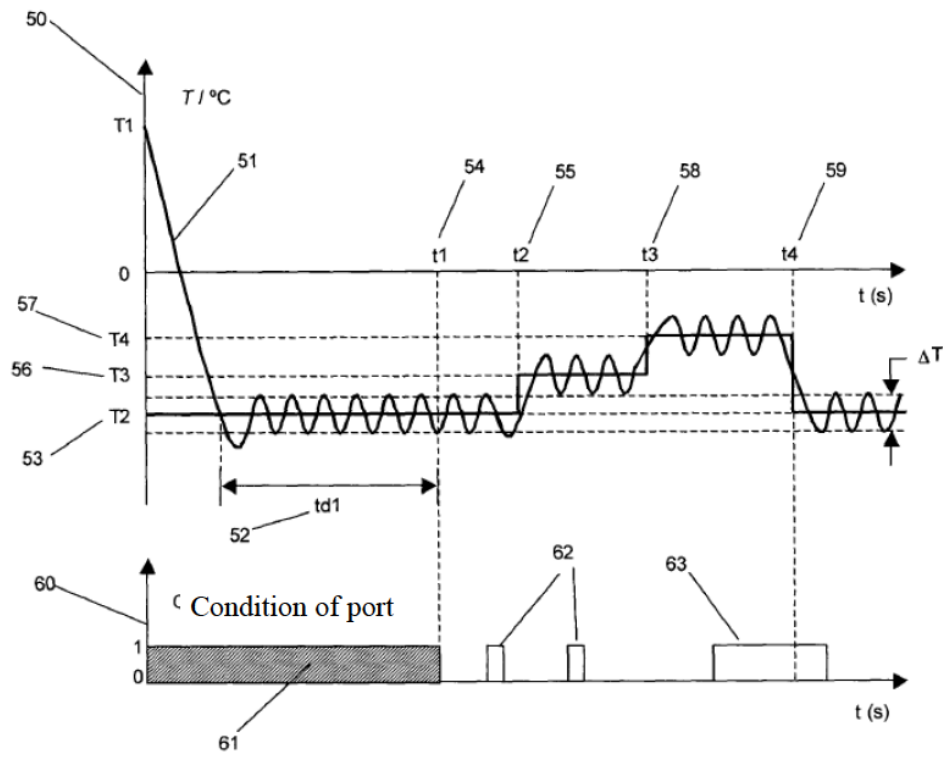


FIG. 2

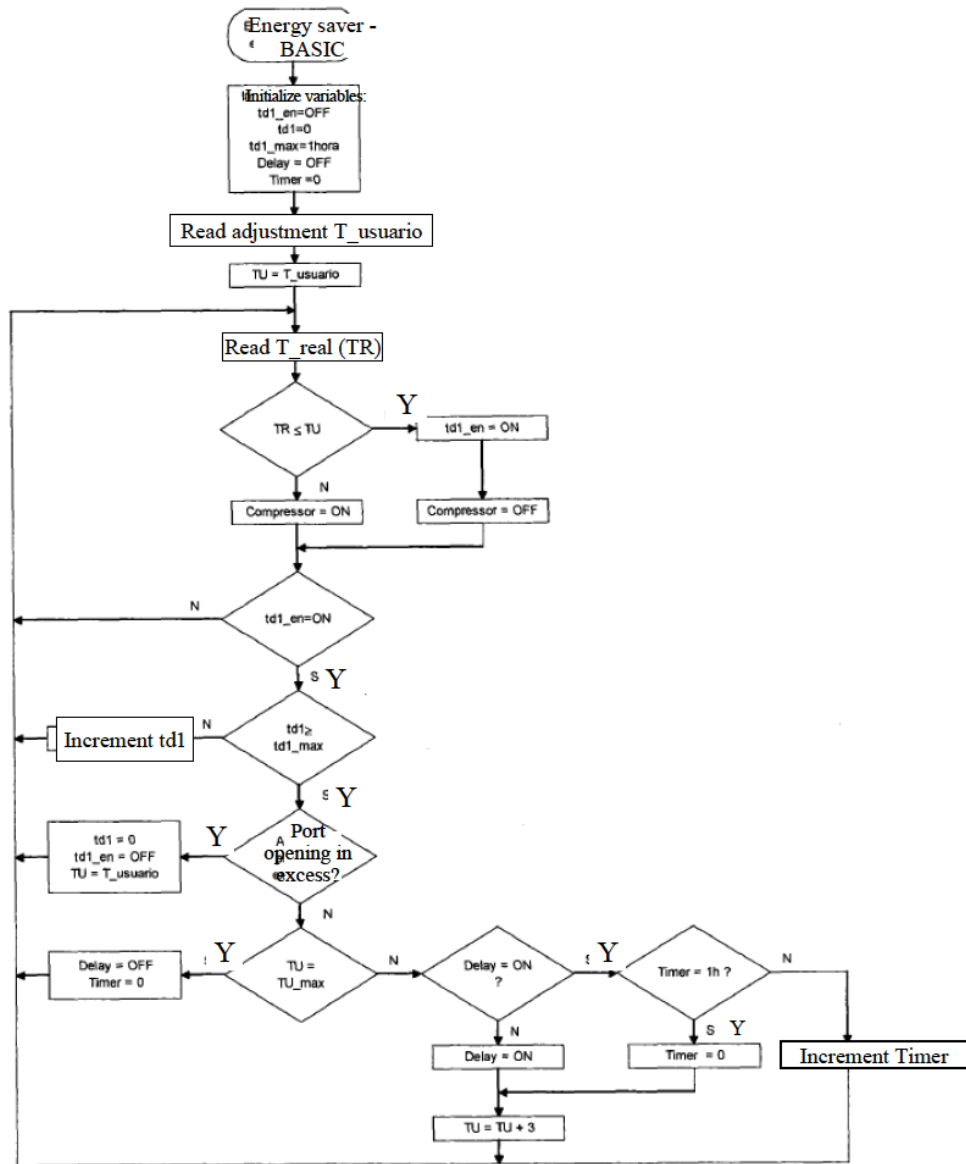


FIG. 3

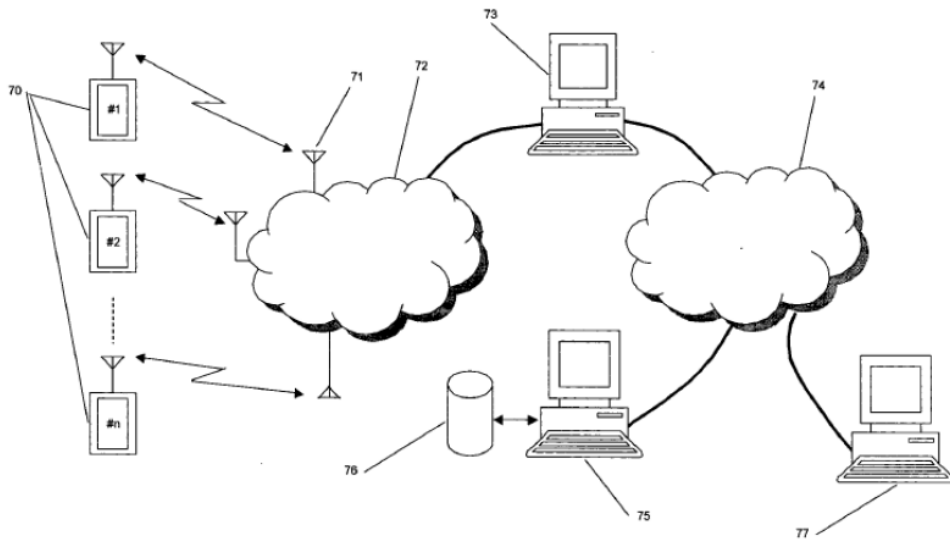


FIG. 4

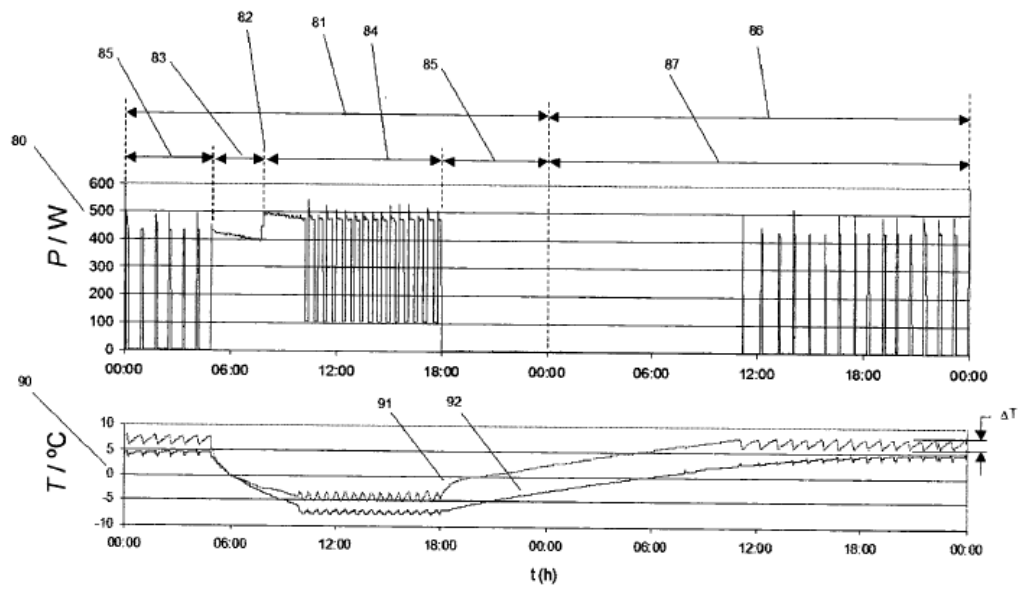


FIG. 5

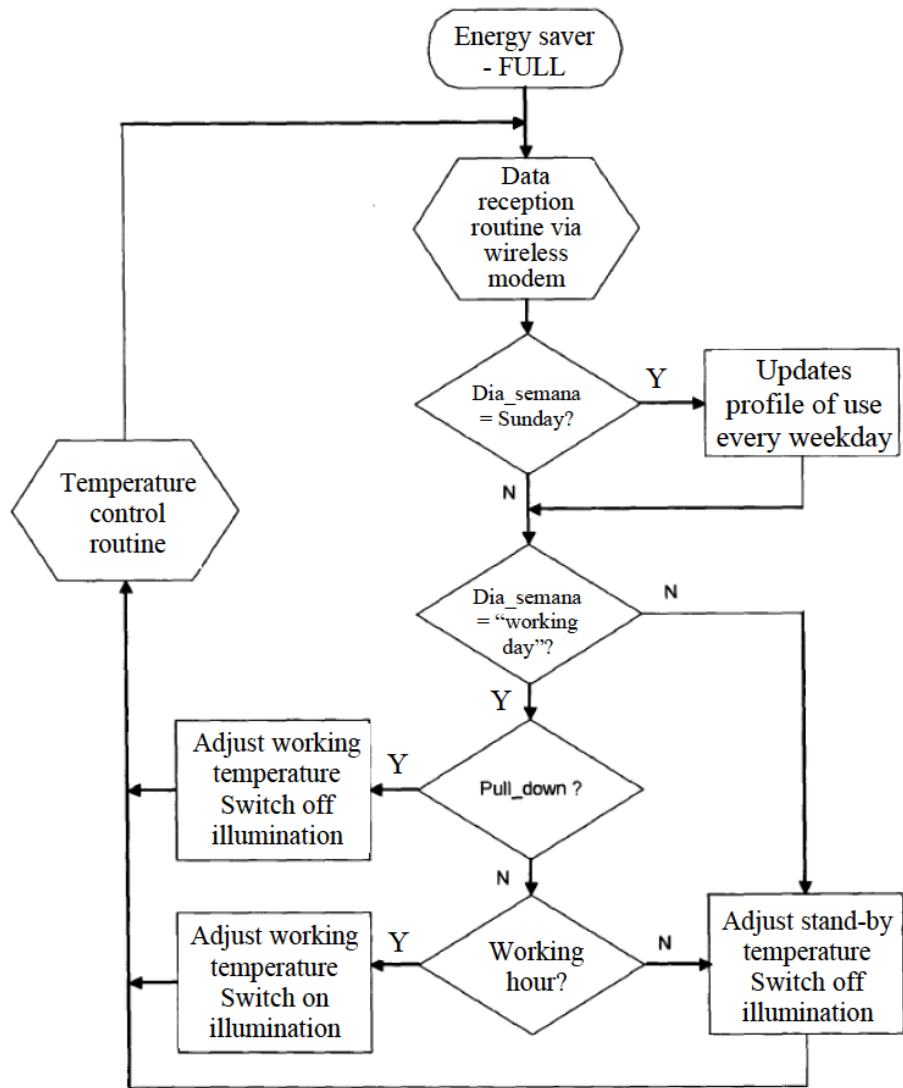
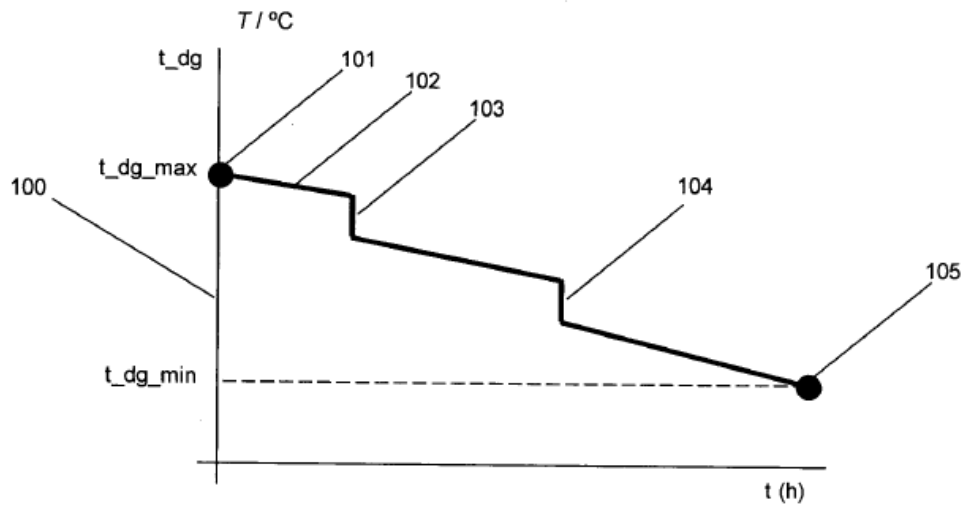


FIG. 6

**FIG. 7**

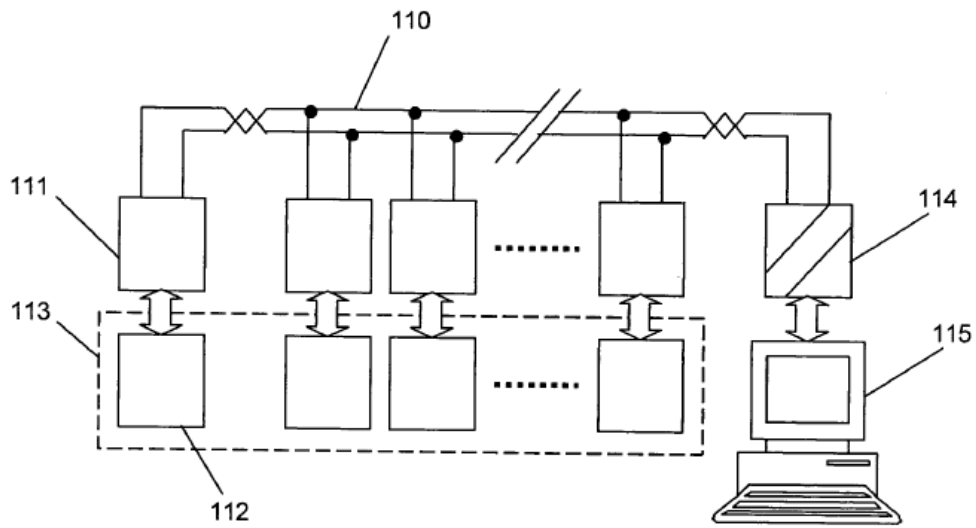


FIG. 8