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An Automated System for Irrigation and Frost Protection

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Abstract

This paper describes details of the design and instrumentation of an automated system for irrigation and frost protection, comprising a soil moisture sensor and a temperature sensor, two water tanks wherein one of them is connected to a heating system, two water level sensors; one in each tank, a pump with automated switching system, two solenoid valves between the pump and each of the tanks, a control unit, an array of sprinklers and at least one solenoid valve between the pump and the sprinklers. The system is also provided with means for emitting acoustical and visual alarms.

Keywords: *Automation, Irrigation, Frost protection.*

1. Introduction

For the purpose of reducing water consumption; many automatic irrigation controllers have been developed in the past [1,2]. Soil moisture has been the major parameter in controlling the irrigation process in a lot of these controllers, wherein a sensor indicate a certain value for soil moisture, a comparator compare this value a preset value and If it was found to be less than the preset value the irrigation process automatically starts by either activating a pump or opening a valve or both. Other Parameters such as ambient temperature were introduced to automatic irrigation controllers but only as additional options wherein the irrigation process is activated by either the soil moisture sensor or the ambient temperature sensor.
As revealed by a review of the prior art, existing techniques focus on activating a sprinkler system either on the bases of a soil moisture sensor readings for the purpose of irrigation or on the bases of a temperature sensor readings to provide protection from frosting [1,2,3,4,5]. Although it has been proven that sprayed water can protect crops from frosting even if it was not heated, and that heated water can satisfy the irrigation needs of crops, no method for utilizing these two function in one automatic system was disclosed in the prior art. So, it would be desired to provide a comprehensive system that integrates the readings taken from a soil moisture sensor and an ambient temperature sensor in one algorithm to perform both functions. Such system will be useful in saving water and the energy concealed in heated water, particularly when a water level sensor in one of the water sources indicates that the source is empty.
The purpose of our system is to protect the corps from dryness and frosting (freezing) while consuming a minimum amount of energy and water, and without the need of constant human monitoring. Taking into consideration that both heated and unheated water will be sufficient for irrigational purposes and that the relatively high specific heat of water will help to prevent freezing even if the water was not preheated, the system will alternate between the two tanks based on the readings of the water level sensors, the temperature and the soil moisture sensors.

2. System Description

The proposed system provides a method in which a controller uses the soil moisture values and the ambient temperature value to automatically affect the operating periods of a sprinkler irrigation system wherein the sprayed water is used as an irrigation source and as a mean to protect against frosting. The systems draws water from two tanks wherein one of them is connected to a solar heating system, both tanks are provided with water level sensors connected to the controller. The controller is programmed with a pre set minimum ambient temperature value, and with a preset minimum soil moisture value. The controller will compare the readings of the soil moisture sensor and the reading of the ambient temperature sensors to the preset values. If any or both of such readings are found to be less that the preset values, the controller will activate the pump and open the specified valves but only after checking the water level sensors readings. The heated water tank is the default source of water in case only the ambient temperature sensor reading drops below minimum, while the

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ambient temperature water tank is the default water source in case only the soil moisture sensor reading drops below minimum, but in case on of the tanks is empty or in case both the moisture sensor and the temperature sensors readings drops below minimum, the controller program will alternate between the two water sources to save water and to protect the pump from operating on an empty tank.

2.1. Detailed Description

FIG. 1 schematically illustrates an irrigation and frost protection system configured in accordance with a preferred embodiment of the system, such embodiment consists of a number of components including a pump 1, a control unit 2, a plurality of irrigation sprinkler heads 3, a soil moisture sensor 4, a temperature sensor 5, a water tank 6 wherein the water is kept at the ambient temperature , a water tank 7 wherein the water is heated using a solar heating system 8, at least one solenoid valve 9 between the pump 1 outlet and the sprinkler heads 3, a water level sensor 10 inserted in the ambient temperature water tank 6, a water level sensor 11 inserted in the heated water tank 7, solenoid valve 12 between the pump 1 inlet and the ambient temperature water tank 6, and a solenoid valve 13 between the pump 1 inlet and the heated water tank 7. As discussed, the irrigation system includes a control unit 2, wherein such unit comprises a microcontroller 14, a liquid crystal display(LCD) 15 for viewing a visual alarm signal, and a siren speaker 16 for emitting an acoustic alarm signal. In a preferred embodiment, the control unit may include a switch 17 used to disconnect the siren speaker manually, for the convenience of the user. The input ports of the microcontroller 14 are connected to the soil moisture sensor 4, the temperature sensor 5, the water level sensor 10 which is inserted in the ambient temperature water tank 6, and the water level sensor 11 which is inserted in the heated water tank 7. The output port of the microcontroller chip 14 are connected to solenoid valve 9 which is located between the pump1 outlet and a plurality of sprinkler heads 3, the solenoid valve 12 which is located between the pump 1 inlet and the ambient temperature water tank 6, the solenoid valve 13 which is located between the pump 1 inlet and the heated water tank 7, the LCD 15, the siren speaker 16 and the switching element of the pump 1. The microcontroller 14 must include a central processing unit, discrete input and output bits, input and output ports, volatile memory (RAM) for data storage and ROM, EPROM, EEPROM or Flash memory for program and operating parameter storage, clock generator, and analog-to-digital converters. Microcontroller models including such features are available and known to those skilled in the art, the microcontroller 14 incorporated in the discussed embodiment of the present system may be anyone of them. Although water tank 6 is referred to as the ambient temperature water tank, in a preferred embodiment of the present system, both tanks are kept under the surface of the ground to provide a slightly higher temperature degree for the water contained in such tanks. To simplify the understanding of the system, the schematic diagram in Fig. 1 is plotted only for one sprinkler head 3. In such diagram the solenoid valve 9 is connected directly to the sprinkler head 3. To apply such embodiment for a plurality of sprinkler heads 3, the system must includes an equal number of solenoid valves 9, wherein such solenoid valves 9 are all connected to the same output port of microcontroller 14 and shall receive the same out put signal. In another embodiment, all pipe lines leading to sprinkler heads 3 will be branched from a single solenoid valve 9, in such embodiment, the length of the pipelines connecting between solenoid valve 9 and each sprinkler head 3 must be equal.

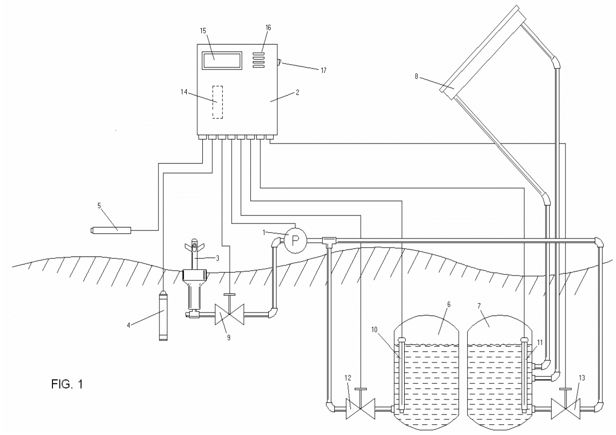

Fig. 1 Schematic diagram of the whole system/

2.2 System Flow Chart

Having described the overall hardware configuration of the system in conjunction with the schematic diagram of FIG. 1, reference is now made to the flow chart of FIG. 2 for an understanding of the software algorithm employed in the microcontroller.

2.2 Hardware Installing and Initializing

Referring to FIG. 2, the operation starts by installing and initializing the hardware, the algorithm will immediately check the value of the ambient temperature sensor 5 at block 18 (which Is also referred as step A), the algorithm will then compare this value at decision block 19 to a preset value that is considered to be the minimum temperature degree at which the frosting process starts. If the test at decision block 19 indicates that the value measured by the ambient temperature sensor 5 is less than the preset value, the algorithm will not start the sprinkling process immediately but it will rather check the reading of the water level sensor 11 at the heated water tank 7 at block 20 to prevent operating the pump 1 while the tank is empty. The algorithm will then test at decision block 21 if this reading indicates that the heated water tank 7 is empty. If the test at decision block 21 indicates that the heated water tank 7 is empty, the system will benefit from the high specific heat of the water which make it suitable for preventing frosting to a certain degree even at ambient temperature and therefore the algorithm will check at block 22 the reading of the water level sensor 10 at the ambient temperature water tank 6 to see if the system can sprinkle ambient temperature water as a backup procedure. The algorithm will then test at decision block 23 if this reading indicates that the ambient temperature water tank 6 is empty. If the test at decision block 23 indicates that the ambient temperature water tank 6 is empty, this will mean that both tanks are empty and therefore the system will take no action regarding the activation of the pump 1 or the solenoid valves but will rather activate the siren speaker 16 and display a preprogrammed massage at the LCD 15; saying that "both tanks are empty" (block 24, which is also referred to as step D).The algorithm will then return to step A, wherein the value of the temperature sensor 5 is checked again to assure a recurrent polled operation. The visual massage displayed at the LCD 15 will remain apparent until the algorithm incorporated in the microcontroller 14 states otherwise, while the acoustic signal emitted by the siren speaker 16 can be deactivated either by the algorithm through the microcontroller or by a manual override procedure. The manual override procedure must not interfere with the algorithm of microcontroller 14 and are design thereto, in a preferred embodiment; a single pole, single throw switch 17 between the siren speaker 16 and the power source.

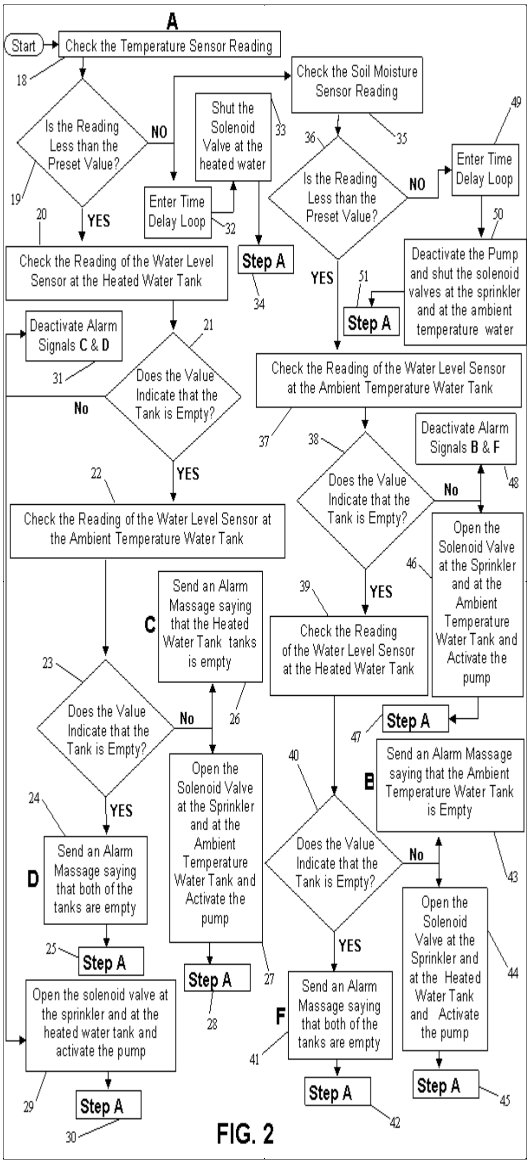

Fig. 2. Flow chart showing operating steps of the system.

If the test at the decision block 23 indicates that the ambient temperature water tank is not empty, the solenoid valve 9 at the sprinkler head 3 and the solenoid valve 12 at the ambient temperature water tank 6 will be opened, and the pump 1 will be activated (block 27), which will initiate the sprinkling process of ambient temperature water as a backup procedure for preventing crops frosting. At the same time, the siren speaker 16 will be activated and a preprogrammed massage saying that the "the heated water tank is empty" will be displayed at the LCD 15 (block 26 which is also referred as step C). After executing the commands in block 27, the algorithm will return to step A, wherein the value of the temperature sensor 5 is checked again to assure a recurrent polled operation (block 28). If the test at the decision block 21 indicates that the heated water tank 7 is not empty, the solenoid valve 9 at the sprinkler head 3 and the solenoid valve 13 at the heated water tank 7 will be opened and the pump 1 will be activated (block 29), which will initiate the sprinkling process of heated water as the default procedure for preventing crops frosting. At the same time, the algorithm will send at block 31 through the microcontroller 14 a deactivation signal to the alarm processes initiated at step C and step D. As known to those skilled in the art; a deactivation signal in a microcontroller is zero voltage signal sent through the output ports leading to the designated components, therefore, if no alarm signal were active during the execution of block 31, nothing will happen, which exactly the desired result in this case, but if the alarm signals at either step C or step D where active as a result of a previous execution of the polling procedure, this signal will be shutdown, to indicate that the heated water tank 7 is now not empty. After executing the commands in block 29, the algorithm will return to step A, wherein the value of the temperature sensor 5 is checked again to assure a recurrent polled operation (block 30).

2.2.1 Soil Moisture Sensing

Having discussed all the steps consequent to the test result of the decision block 19 indicating that the value measured by the temperature sensor 5 is less that the preset value, attention should be directed to the fact that the soil moisture sensor reading is never to be checked through the whole sequences, starting from block 20 and ending with block 30, 28 or 25. The reason for designing the algorithm in such manner is that heated water will satisfy the irrigation needs of the crops to the same extent of ambient temperature water. Therefore, incase the value measured by the soil moisture sensor indicates that the crops need irrigation, either sequences leading to block 30 or to block 28 will satisfy that need, while nothing can be done in the sequence leading to block 25 , except sending an alarm signal, regardless of the value measured by the soil moisture sensor; since both the tanks are empty. Continuing reference to FIG. 2, in case the test at the decision block 19 indicates that the value measured by the temperature sensor is higher than the preset value, such result means that the frosting problem do not exist and therefore the system doesn't need to spray water as a solution to such problem. The logical response to such result will be to terminate any process implemented to prevent the frosting problem in a previous execution of the polling procedure. As discussed, processes implemented to prevent frosting includes activating the pump 1 (block 27 or block 29), opening the solenoid valve 9 at the sprinkler head 3 (block 27 or 29), and opening either solenoid valve 13 at the heated water tank 7 (block 29) as a part of the main frosting prevention procedure or the solenoid valve 12 at the ambient water temperature tank 6 (block 27) as a part of the backup frosting prevention procedure, but though, only solenoid valve 13 at the heated water tank 7 will be shut (block 33), the shutting process at block 33 will be delayed for a preset period of time (block 32), such period is applied as a precautionary measure to prevent instantaneous opening and shutting of the valve. In order not to conflict with the technical problem solved by the present system, which is to save water and energy, such period must not exceed 2 minutes. After executing the commands in block 33, the algorithm will return to step A, wherein the value of the temperature sensor 5 is checked again to assure a recurrent polled operation (block 34). Other processes implemented to prevent frosting, which comprises activating the pump 1 (block 27 or block 29), opening the solenoid valve 9 at the sprinkler head 3 (block 27 or 29) and opening the solenoid valve 12 at the ambient water temperature tank 6 (block 27) will not be terminated at this stage, the implementation of such processes might be a result of actions taken in consequences to checking the value measured by the soil moisture sensor 4 (block 35) as will be discussed further, and as its known to those skilled in the art, designing the algorithm so it can check for the source of an implemented action in a previous executed polled procedure will add unneeded complication to the system. When the algorithm decides to initiate the time delay period (block 32), it will simultaneously check the value measured by the soil moisture sensor 4 (block 35), the algorithm will then compare this value to a preset minimum soil moisture value (block 36), if the measured soil moisture value drops below such minimum value the soil will be considered to be dry and the crops need irrigation accordingly, therefore, if the test at the decision block 36 indicates that the value measured by the soil moisture sensor 4 is less than the preset value, the steps needed for irrigation will be initiated. As discussed, both heated water and ambient temperature water will satisfy the irrigation needs of the crops to the same extent, but to save energy concealed in heated water, the ambient temperature water tank 6 will be the default irrigation water source, therefore, the first action executed by the algorithm, incase the test at decision block 36 indicates that the value measured by the soil moisture sensor 4 is less than the preset value, will be to check the reading of the water level sensor 10 at the ambient temperature water tank at block 37 to prevent operating the pump 1 while the tank is empty. The algorithm will then test at decision block 38 if this reading indicates that the ambient temperature water tank 6 is empty. If the test at decision block 38 indicates that the ambient temperature water tank 6 is empty, the algorithm will check at block 39 the reading of the water level sensor 11 at the heated water tank 7 to see if the system can sprinkle heated water as a backup procedure. The algorithm will then test at decision block 40 if this reading indicates that the heated water tank 7 is empty. If the test at decision block 40 indicates that the heated water tank 7 is empty, this will mean that both tanks are empty and therefore the system will take no action regarding the activation of the pump 1 or the solenoid valves but will rather activate the siren speaker 16 and display a preprogrammed massage at the LCD 15; saying that "both tanks are empty" (block 41, which is also referred to as step E).The algorithm will then return to step A, wherein the value of the temperature sensor 5 is checked again to assure a recurrent polled operation. If the test at the decision block 40 indicates that the heated water tank 7 is not empty, the solenoid valve 9 at the sprinkler head 3 and the solenoid valve 13 at the heated water tank 7 will be opened, and the pump 1 will be activated (block 44), which will initiate the sprinkling process of heated water as a backup procedure for irrigation. At the same time, the siren speaker 16 will be activated and a preprogrammed massage saying that the "the ambient temperature water tank is empty" will be displayed at the LCD 15 (block 43 which is also referred as step B). After executing the commands in block 44, the algorithm will return to step A, wherein the value of the temperature sensor 5 is checked again to assure a recurrent polled operation (block 45). If the test at the decision block 38 indicates that the ambient temperature water tank 6 is not empty, the solenoid valve 9 at the sprinkler head 3 and the solenoid valve 12 at the ambient temperature water tank 6 will be opened and the pump 1 will be activated (block 46), which will initiate the sprinkling process of ambient temperature water as the default procedure for irrigation. At the same time, the algorithm will send at block 48 through the microcontroller 14 a deactivation signal to the alarm processes initiated at step B and step E. As discussed; a deactivation signal in a microcontroller is zero voltage signal sent through the output ports leading to the designated components, therefore, if no alarm signal were active during the execution of block 48, nothing will happen, which exactly the desired result in this case, but if the alarm signals at either step B or step F where active as a result of a previous execution of the polling procedure, this signal will be shutdown, to indicate that the ambient temperature water tank is now not empty. After executing the commands in block 46, the algorithm will return to step A (block 47), wherein the value of the temperature sensor 5 is checked again to assure a recurrent polled operation. In case the test result at the decision block 36 indicates that the soil moisture value measured by the soil moisture sensor 4 is higher than the preset value, which means that the crops does not need irrigation , all processes implemented in a previously executed polled procedure to initiate an irrigation process will be terminated . As discussed, the solenoid valve 13 at the heated water tank 7 has already been shut at block 33, this step is a part of the only sequence in the algorithm that will lead to decision block 36. Therefore, after the system waits for a preset value of time (block 49), only solenoid valve 12 at the ambient temperature water tank 6 and solenoid valve 9 at the sprinkler head will be shut, the pump 1 will be also deactivated simultaneously (block 50). After executing the commands in block 33, the algorithm will return to step A (block 51), wherein the value of the temperature sensor 5 is checked again to assure a recurrent polled operation. The time delay in block 49 is used as a precautionary measure to prevent instantaneous opening and shutting of the solenoid valves and instantaneous activation and deactivation of the pump.

3. Future work

Although the above description of the present system has disclosed the features of the system as applied to the various embodiments; additions, omissions and modifications applied to the details of the embodiments illustrated may be made by those skilled in the art without departing from the essential characteristic of the present system. Such changes may include adding a data acquisition unit to store the readings of the soil moisture sensor 4 and the temperature sensor 5 and using the stored date for analytical and comparative purposes along seasons. The system can also be easily modified by those skilled in the art to comprise plurality of soil moisture sensors 4 and temperature sensors 5 for each area covered by a single pump 1; which will increase the accuracy of the system. Consequently the described embodiments are to be considered in all respects only as illustrative and not restrictive.

4. Conclusion

This paper proposed an efficient method for automatically irrigating crops and automatically protecting such crops form frosting, comprising means for measuring soil moisture value, means for measuring ambient temperature value, means for measuring water level at a heated water source, means for measuring water level at an unheated water source, means for activating and deactivating a pump, means for opening an shutting valves between the pump and the water sources, means for opening an shutting valves between the pump and water sprinkler heads and means for activating and deactivating alarm signals.

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