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MODEL BASED REAL TIME AUTOMATED TEMPERATURE CONTROL SYSTEM FOR RISK MINIMIZATION IN HONEY BEE WINTERING BUILDING

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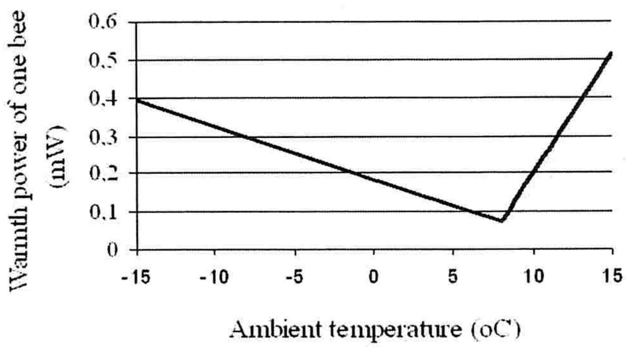
Abstract

During the winter time honey bees can be placed in a special wintering building to save physiological resources of bees and honey compared with outdoor wintered bees. This building should have stable and convenient microclimate conditions for bees. The most important parameter of microclimate to be controlled is temperature. For our bee wintering building we have developed a special temperature control system, using a programmable logic controller (PLC) that is permanently connected via Internet to the model based risk management system. The developed system helps to minimize honey bee wintering risks. The possible risks are the start of intensive brood rearing before early spring and the risk of control system failure. To minimize technical system errors *SMS* and e-mail notifications are used.

Introduction

Our task is to maintain stable climate conditions in constructed experimental honey bee wintering home. At the moment the single measured and controlled parameter is temperature, but in the future the count could be extended with other needed parameters, for example humidity, pressure etc. Temperature is the primary climate parameter and during the winter time it is needed to maintain the constant temperature in the building. The ambient temperature of +8°C corresponds to the lowest warmth power produced by bees (see Figures 1) and therefore it is the desired temperature in the building.



Figures 1: Dependence of bee warmth power from ambient temperature (Jeskov 1983)

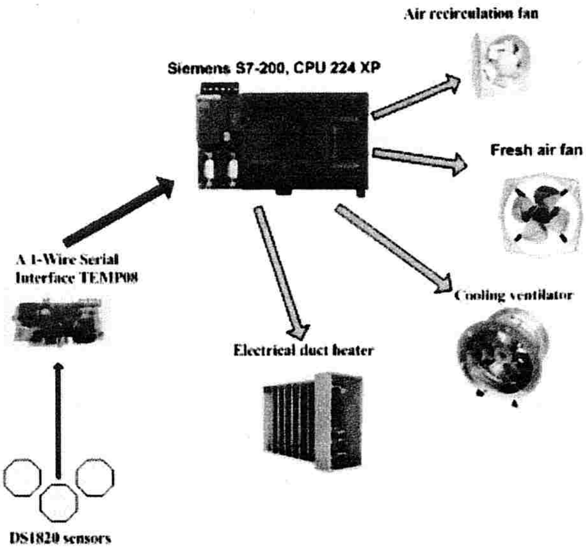
If temperature is on this level, honey bees are consuming the least amount of feed. Sharp fluctuations in temperature have negative effect on bees. As a result of such fluctuations the density of the bees cluster could change, crystallization of honey in the comb accelerates and dampness could be induced in the hive. Significant temperature increase has the most negative effect on bees. This can lead to a situation, when bees would come to the active state of intensive bee breeding too early and bee queen would start to lay eggs. Too early start of bee breeding in the winter can cause high energy consumption of bee colony that, in turn, can lead to a possible death of that colony. That is the main risk factor during the wintering in the special building. In case of increased activity of colonies the target temperature should be decreased according to a model.

Wintering building and temperature control system

The honey bee wintering building is a building with size 6,25m x 4,00m x 2,4m made from sandwich panels with wall thickness of 80 mm and the roof 100 mm (Osadcuks and Stalidzans 2008). The developed control system is based and controlled by the PLC. In our case we are using Siemens S7-200 controller with CPU 224XP (Berger 2000). PLC is a digital computer used for automation of electromechanical processes and it is designed for multiple input and output arrangements. PLC controls other equipment in the building (see Figures 2). The controlled equipment is:

- Air recirculation fan for homogenising the air and its temperature inside the building;
- Cooling ventilator system;
- Fresh air fan;
- Electrical duct heater.

The main task of the system is to control the temperature changes. Temperature is measured, using the DS18S20 sensors. Duct heater is functioning using the PLC integral PID algorithm. The air is heated till the target temperature is reached. PLC user program is written using the Ladder Diagram programming language. (Berger 2001)



Figures 1: Temperature control system elements

Risks minimization of bee wintering

Bee wintering buildings generally do not need human attendance during the winter and therefore automatic control system usually functions unattended for a long period of time - weeks or even months. PLC controls all other control system components, such as sensors, heaters, fans and other. Several risks have to be considered: 1) start of intensive brood rearing before early spring and 2) failure of the control system itself.

If intensive brood rearing of colonies starts during the winter (instead of early spring) the whole bee colony could die. Another risk is the failure of the control system elements. The death of bee colonies can occur due to overheating, overcooling or lack of oxygen.

The detection of the risk of early start of brood rearing can be done placing temperature sensors between the bee nest and pillow. The rapid increase of temperature is a signal of a potential start of intensive brood rearing. Never the less, additional calculations using the model of bee colony dynamics should be used to determine the significance of early brood rearing risk. The communication of PLC with the central computer in the office allows using the model located in the office computer and make intensive calculations. These calculations cannot be done on PLC which is installed in the bee wintering building. In case of risk, the target temperature of the wintering building can be decreased automatically or after a confirmation by beekeeper.

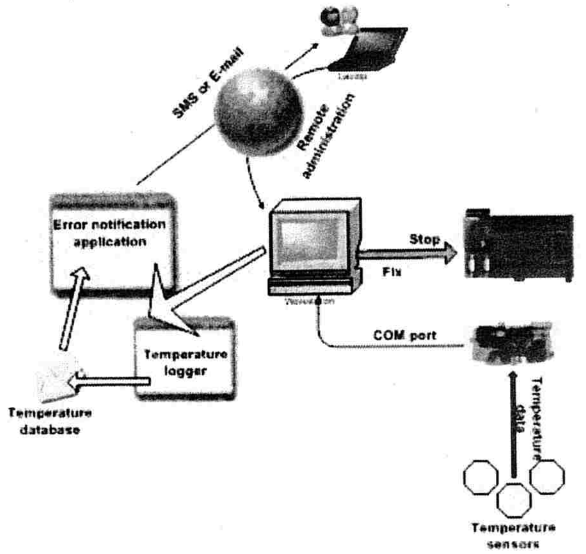
The solution for minimizing equipment failure risk could be realized by applying error notification method. For example, when the temperature reaches the critical limit, it is important to inform the responsible person or persons (beekeepers) about this. The critical temperature limit is defined in the system by a system user. Notification methods that can be realised are *SMS* or e-mail sending. But *SMS* sending is a more efficient way of notification, because beekeepers will receive the error message without any significant time delay, but e-mail could be read after some time, when PC will be used. But in our case the reaction from beekeepers is needed immediately, if they want to save their honey bees.

We have realised the error notification method in such a way. In the honey bee wintering building we have placed four DS18S20 temperature sensors which are directly connected to TEMP08 Serial One Wire Interface. (http://www.midondesign.com/TEMP08/TEMP08.html.)

This device is connected to a PC using the standard serial interface RS232. We have also developed two related PC applications, using the C# programming language. The idea of the first program is to monitor the temperature sensors by receiving data using the COM port of the PC. Program user can change the time intervals to define how often it is needed to receive the temperature data from the sensors. The interval can be, for example, one minute or one hour. Then all received data is stored in the MS Access database. In the program we have also added some visualisation of data, so that the user can see the chart of temperature values. Other program functionality can be added as needed. So this program could be named as temperature logger. (Meitalovs et al. 2009) The second program is named as error notification application. It uses data from the mentioned database. Every time when temperature data is taken from it, it is saved in a simple txt file. Every day a new txt file is created and once a day it is sent to beekeeper's e-mail. This is needed to give him a possibility to check whether the system is working properly. But the main task of the program is to check whether the temperature is within critical limits and if temperature is out of these limits *SMS* is automatically sent to responsible persons for an immediate reaction.

One more feature that was developed is a remote connection to the PC, which is connected to the PLC device. This feature allows the beekeeper to remotely access the logical part of temperature control system. This option is not needed if beekeeper can easily access bee wintering building and fix or change the control system program on site. But if this is not possible or the responsible person is far away from bees, then remote connection is the right way to solve small program problems or fix errors. In our case we are using standard MS Windows remote connection application for remote access to the PC. And beekeeper can access his control system from any other PC. One more reason of using remote connection rather than fixing errors on site is that it is not recommended to use light in the honey bees wintering building, while solving system problems in the dark is not very comfortable and easy.

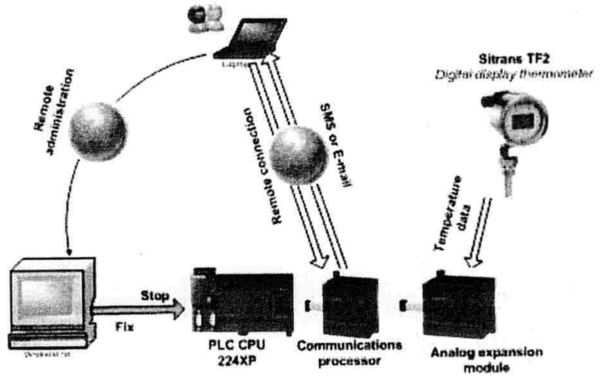
So in that way we are minimizing the risk of system errors (see Figures 3). But of course, there are also other risk factors left. For example Internet connection to the bee wintering building could be broken and then we will not receive any error notification messages.



Figures 2: Realization model for risk minimization of PLC based temperature control system

The future development of the temperature control system

The temperature control system developed by us can be modified and upgraded. The first possible upgrade is to modify error notification system. It would be good to develop it using the PLC communication device, rather than using the separate C# application. So the main idea is to connect PLC device to the Internet using the additional IT communication module (see Figures 4). This will give a possibility for the beekeeper to remotely control the PLC device using its WEB interface. And *SMS* sending process also could be done by this module. The second upgrade could be the measuring of additional parameters in the wintering building. One of the most important additional parameters to be considered is humidity, but the ideal relative humidity for a wintering chamber has not been determined. Some tests show that bee colonies are very adaptable to a wide range of relative humidity situations. Satisfactory level of relative humidity in the wintering building is in the range of 50-75%. (Furgala and McCutcheon 1992) When humidity is too low, bees are suffering from thirst and to quench it, bees have to consume honey strenuously, but this could lead to diarrhoea disease. But when humidity is on high level, crystallization of honey accelerates and bees become very loud, crawl out of the hive and die. Also mice cause great concern for bees, and that is way it is needed to detect them on time. To complete this task some floor movement sensors could be used.



Figures 3: The future development of the temperature control system

Conclusions

The developed temperature control system is used for maintaining stable microclimate in honey bee wintering building. The main controlled parameter is temperature, because it has the major impact on bees during the wintering time. The control system is based on PLC, which is used to control equipment needed for heating the air in the building. The controlled equipment consists of air recirculation fan, cooling ventilator system, fresh air fan and electrical duct heater. Temperature data is received using the DS18S20 sensors. The developed temperature control system helps to minimize such honey bee wintering risks as 1) start of intensive brood rearing before early spring and 2) failure of control system. Error notification system is developed to minimize PLC control system risks. Advised notification method is *SMS* sending to one or more mobile phones. E-mail notifications could be used as well.

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