

DEVELOPMENT OF A KNX-BASED GREENHOUSE CLIMATE CONTROL

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The base of this paper is built on the work in progress focused on the applicability of the KNX technology for protected cultivation industry. The authors present a description of this application area, which is new for the KNX, by providing the details and requirements of the climate control systems used in greenhouses. As an example of specific application domain, a control of humidity level is highlighted in the paper. The general concept of a KNX-based control system, which was worked out upon found constraints and limitations, could be used for the integration of the greenhouse control into a global enterprise management system.

1. INTRODUCTION

Greenhouses (also called glasshouses in Europe) evolved to be a very significant part of the agriculture and allow producing fresh fruits and vegetables all year round, also out of the season, or cultivating crops not usual for climatic conditions of certain regions. When thinking of a huge market for cut flowers, grown in the greenhouses accordingly to up-to-date fashion or by specific date, it becomes clear that protected cultivation is a very specific business area, which for successful operation needs knowledges and techniques from various sciences.

The target of the commercial purpose greenhouses, like in any other business, is to maximize profit, which depends directly on the yield grown. Very similar to human beings, plant species perform their best while being in the most comfortable environment, which in their case understands keeping the temperature, light and humidity at the optimal level for photosynthesis. The greenhouse owners make investment into the improved covering materials, able to allow more sunlight into greenhouse and yet reduce heat losses during winter. New growing media are being invented, modification and reconstruction of heating and irrigation systems is being fulfilled. Computerized environmental control systems allow an individual the ability to integrate the control of all systems involved in manipulating the growing environment, thus improving the crop development and reducing the production costs.

Beside the commercial purpose greenhouses, there is a number of facilities for performing experiments related to plant growth research, where a high degree of the climate control is needed, too. Acquisition and processing of the environmental data is very often important both for horticultural research and for long-term planning of a company's policy.

Nowadays there are numerous greenhouse environmental control systems presented on the market, offering as much or as little of the control as may be feasible. Though they have certain disadvantages of the proprietary solutions., and first of all lack of flexibility and system scalability, dependance on the manufacturer one starts to work with, which means less safety for the investments. That is why the certain trends and features of the KNX, a standardized building automation technology, could find their use when applied for greenhouse control. The current work is concentrated on the investigation of both industries, with the goal to find the edge where the control systems developed for building automation industry can meet the constraints and requirements of the protected cultivation.

2. COMPARATIVE ANALYSIS OF GREENHOUSES AND BUILDINGS AS CONTROL OBJECTS

Although some applications used in greenhouse controls are very domain specific and not presented in the KNX (e.g. nutrition control), climate controls in protected cultivation structures consist of the same components as those met in residential and non-residential buildings, namely heating, cooling,

ventilation, air-conditioning, supplementary lighting systems. Just a few differences must be considered, which present the most challenge for the building automation systems. Due to the intensive plants response to the changing conditions and the interdependence of the controlled variables, the dynamics of the growing environments is very complex. The sensitivity of crop as well as some features of greenhouse constructions and horticultural business in general, which will be described later in the paper, causes additional constraints and limitations. Though once the solution is found, the KNX will provide the greenhouse climate control with all the advantages it has, in particular transparent installation, ease of technical maintenance, flexibility and scalability, independence from manufacturers both in choosing the appropriate systems for present operation and for future needs, as well as integration into higher levels of building/enterprise management systems.

2.1. Greenhouse specific requirements

The primary goal of the modifications made to the greenhouse environment is to maximize the crop production, which means to obtain the maximum rate of photosynthesis. This can be achieved by manipulating light, temperature and humidity variables. The containment for the controlled indoor environment represents a barrier to the external disturbances (e.g. sunlight, wind, etc.). An individual can choose various materials and techniques for the most efficient and energy saving design of residential and non-residential buildings to make them less dependent on the outside weather conditions, but the greenhouses shall be designed in a way, which allows the entire structure to work for the plants development and make use of the natural sources, especially of the solar radiation. This limits the covering materials and width of the roof and walls to those, which allow maximum light penetration to the growing crops. At the same time such constructions are more interdependent with the outside conditions.

The difference of climate control in buildings and in greenhouses is also resulted from different degrees of interactions between the environment and its “inhabitants”. People can perform some active influence on the controlled *equipment*, which leads to changes in the air temperature or humidity. The greenhouse environments are more complex and dynamic because of the intensive interactions between the internal *climate variables* and the plants being grown there. Greenhouse models (physical models like heat or energy balances, rule-sets, fussy representation of the dynamic environments, etc.), used to predict the greenhouse state in 15-60 minutes, involve numerous variables, such as internal temperature (with subsets of air, cover, plant root/head zones, leaves surface temperatures), humidity, heating valve positions, pH level, carbon dioxide level, and many others. The same holds for the optimization algorithms developed for the better performance of the equipment to be controlled.

The objective of building automation systems is to provide humans with comfortable and safe working or living conditions, which usually means keeping “comfort” setpoints during several hours a day (depending on the room occupancy) and working in the energy-saving mode the rest of the time. On the contrary, greenhouse plants need 24-hour monitoring and control, which must be very smooth and accurate because of plants sensitivity.

Depending on the crop cultivated in a greenhouse, its indoor conditions need to be controlled in different ways. For some plants the day-night temperature fluctuations are less important but the stable average temperature within several days affects the way of plant development. Also several temperature setpoints within 24 hours could be defined upon the plant growing phase and the crop diurnal schedule. The right temperature is the variable, which defines to the large extent the depth of the flowers colour or the time of the flower maturation. Knowing this dependance, for example, a grower can lower the temperature to delay plants development in order to deliver more flowers on Monday rather than running the same temperature over the weekend.

Humidity is a big challenge in the greenhouse automated environmental control. Too low or too high relative air humidities affect the transpiration rates by difference in air pressure and pressure in the leaf. Too low humidity leads to situations where plants slow or halt the growth process, being unable to receive enough water from the roots. At high humidities, the pressure differential is not enough to support the needed transpiration rate. No transpiration means no movement of nutrients through the plant, and it is starved. Besides, wetness permits some dangerous spores to germinate and infect the plants. Controlling air relative humidity is not a trivial task: raising a temperature means that the air can contain more water vapour, so relative humidity drops, but heating stimulate the transpiration, which means more water is added to the air by plants, and relative humidity increases. That is why it

could be necessary to have heating system and ventilation operating at the same time: heating to keep the desired temperature setpoint and ventilation needed to cope with high humidity. In buildings, such behaviour would consider very inefficient, and open window would lead to switching the heating off. This example shows one of the differences found in maintenance of building and greenhouse indoor climate. Other examples could be particular sequences for operating equipment (both for obtaining the desired setpoints or in order to prevent rapid reversals, which would damage the valuable equipment and lead to undesirable fluctuations in environmental variables).

2.3. Information exchange

Considering greenhouse as a part of a business enterprise, it is necessary to mention information flows. Not only short-term continuous control of the equipment is needed to provide the optimal conditions for the present crop, but also plans going over several weeks or months have impact. These are usually affected with company policy regarding the selection of plants to be cultivated or state holidays when more yield would be required for delivery. Also quality of products, taxes, costs of fuel and labour could force the company management to alterate their greenhouse production strategy.

Acquisition and processing of the environmental data is very important both for climate control and for plant growth related research. To meet this goal, the control system should be able to cope with constant measurements and information flux. Analyzing the historical data, growers can trace the influence of climate conditions on the plants development and thus adjust controlling setpoints for the next crops. Equipment related information is constantly used to ensure proper functioning of the entire system, as well as for avoiding energy load peaks (the system can analyse different ways of achieving the desired climatic state and choose the one, which would be more reasonable from the point of energy use).

3. GENERAL CONCEPT OF A KNX-BASED GREENHOUSE ENVIRONMENTAL CONTROL

Taking into account requirements described in the previous chapters, it is now possible to distinguish several informational components of the greenhouse climate control system:

- 1) *environmental data*, represented by sensors measurements and desired setpoints: air temperature and relative humidity, temperature at the plant root/head zones, carbon dioxide concentration, pH level, outside weather conditions (including wind speed and direction);
- 2) *equipment properties* such as configuration parameters, features of the correct operation (e.g. delays between switching on and off);
- 3) *enterprise / marketing related information*: fuel and labour costs, current expenditures, energy consumptions, taxes, marketing research results, etc.

For technical implementation of the system, which would ensure the appropriate functional performance and information exchange, the following structure is being offered:

at the field level, the KNX installation provides with communication between sensors, actuating mechanisms and related controlling modules for manipulation of heating, lighting, ventilation, irrigating, air-conditioning components as well as safety and security systems. Internal intelligence of the units, implemented within the KNX technology, allows for maintaining the proper equipment operations. Nevertheless, the calculating capacity of the bus participants is very limited and not sufficient for the general system supervision. This task is undertaken by dedicated servers. Recent developments of the KNX allows accessing the bus network over internet protocol. The servers acquire data from the sensors continuously, and run complicated processes of analyzing it and calculating new setpoints and optimized controlling commands. All collected information is then stored in a database, which should provide with remote data access. In this way, it will be possible for authorized persons to monitor and control the greenhouse from any place, without being forced to visit greenhouse facilities. The XML representation of all the information within this installation should allow easy integration of the environmental control into the global enterprise management system and make use of web-services (e.g. retrieving weather forecasts over the Internet in order to predict the greenhouse state in 2 days).

4. CONCLUSION

The presented work is focused of the investigating a new area where KNX could be applied. General concept of a KNX-based greenhouse control system, introduced in the paper, concerns climate control and acquisition of the environmental data as well as the ability of the system to be integrated into the global enterprise information exchange. Differences found in the similar application domains within building automation systems and horticulture industry, represent a certain challenge for the KNX technology. Greenhouse specific functions and constraints need closer look to understand interdependances of the involved systems and control loops employed for the maintenance of the internal climate conditions. The resulted model will present KNX-based facility for plant growth development, horticultural research and for business management.

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