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Utilization of regression analysis to increase the control accuracy of dimmer lighting systems in the Smart Home

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Abstract: The article deals with the possibilities of the use of regression analysis to process data acquired from sensors of the KNX control system used for operational measurement and the control of lighting systems in the individual rooms of the Smart Home and data from the measuring apparatus for long-term illuminance measurement in interior workplaces. The article compares data measured on 24/01/2016 and 30/01/2016 with an overcast and partly clear sky. The article verifies the possibility of using regression analysis to determine the correction curve for the input requirement for the constant lighting level of the KNX control system.

Keywords: Smart Home; Light Control; Regression analysis; KNX.

1. INTRODUCTION

To reduce operating costs of energy consumption and ensure comfortable lighting control in the Smart Home (SH), it is possible to utilize a suitable implementation of modern systems of lighting control. Li (2015) Designed of smart home control systems based on wireless sensor networks and power line communications with implementation of smart control algorithm for lighting systems and an analysis of the illumination of a fluorescent lamp. Lee (2011) proposed ideas for saving energy used for lighting devices by utilizing an individual's record of experiences with regards lifestyles as a key element affecting the lighting energy waste, which is to provide a customized one-to-one lighting device control service using life-log data. Novak (2013) describes possibility to achieve the energy savings by the light control in Smart Home with KNX technology (Vanus (2013a)). Park (2014) performs research on energy-efficient privacy protection for smart home environments using behavioral semantics. Han (2014) proposes a smart HEMS architecture that considers both energy consumption and generation simultaneously with wirelles technology - ZigBee-based energy measurement modules, which are used to monitor the energy consumption of home appliances and lights. El-Shafei (2014) designed a customizable home management system with a surveillance RoBOT, which is an automation system that allows for control over the equipment in a house, such as, ventilation, lighting, power system, security system, etc. Czarnul (2013) presents design of a distributed system for measurements and control of a smart home including temperatures, light, fire danger, health problems of inhabitants such as increased body temperature, a person falling etc. . Vanus (2014a) describes the analysis, development and implementation Vanus (2014b) of the software environment used for communication between the user and the control center and to processes data during visualization application environment creation to achieve comfortable control intelligent (smart) buildings (wirelles technology) with possibility of voice control of operational and technological functions (light, blinds and HVAC control), Vanus (2013b), Vanus (2015b). In this area is possible using a new SW tools or using of commercial SW products too, e.g. for energy management and monitoring of people activities behavior in the Smart Buildings Vanus (2015a). The article describes the utilization of regression analysis to increase the control accuracy of dimmer lighting systems in Smart Home in order to verify the model for the prediction of savings in lighting systems to a constant lighting level by the implementation of KNX technology in room 204. For verification, the data have been used as measured with:

a) operating sensors of KNX illuminance in SH, in room 204 ($E_{knx\ in}$) and outdoor ($E_{knx\ out}$) (Fig. 1)

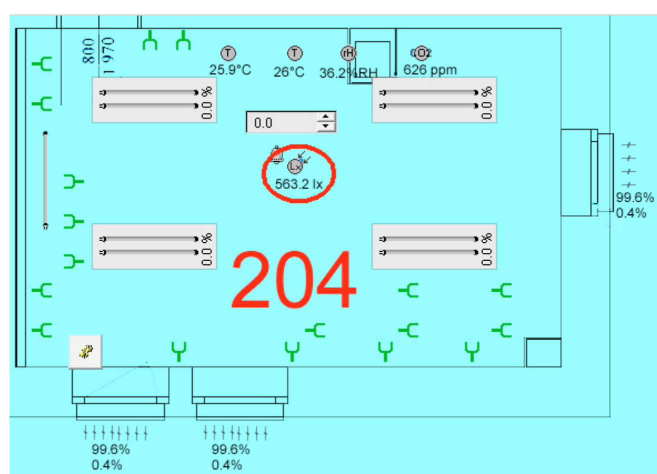

Fig. 1. Location of the KNX sensor measuring illuminance in room 204 ($E_{knx\ in}$) and outdoor ($E_{knx\ out}$ – operational measurement.

b) and precise measurement in conformity with the ČSN EN standards for lighting level measurement in

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room 204 (sensors L1 – L5) and outdoor (sensor L11), (Fig. 2)

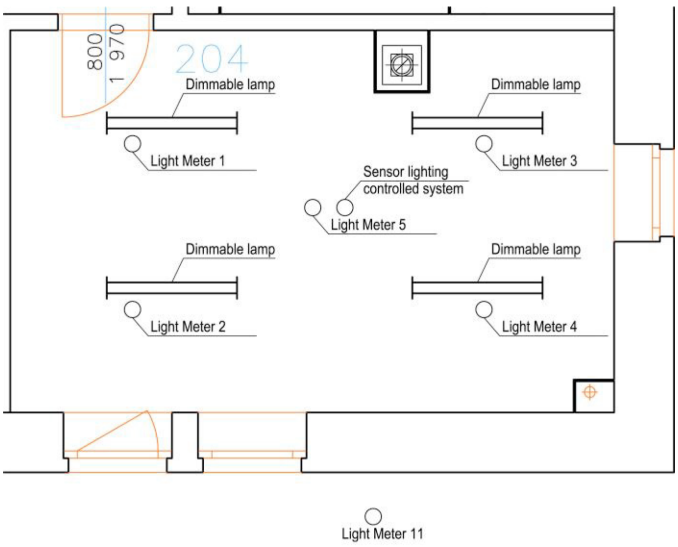

Fig. 2. Layout of sensors for the measurement of illuminance in room 204 – precise measurement.

2. SYSTEM DESCRIPTION – PRECISE MEASUREMENT

The measurement has been designed as automatic, unmanned. Room 204 is equipped with five sensors - luxmeters at the specified points (L1 – L5), (Fig. 2). The last sensor (L11) measuring the illuminance on the outdoor unshaded horizontal plane is located on the SH roof. The sensors are interconnected with the RS485 bus (Fig. 3) using free raceways in the structured cabling; the measuring computer is located in the data switchboard room. Data collection from all sensors is executed every 10 seconds.

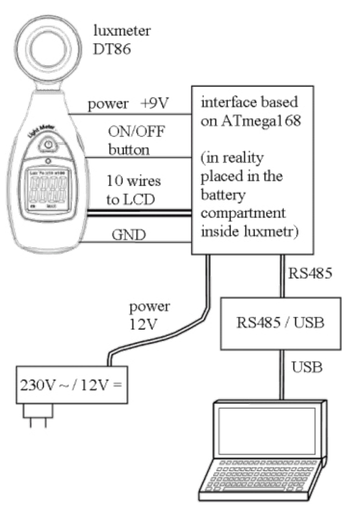

Fig. 3. Schematic diagram of the luxmeter-computer connection.

For lighting level measurement, DT86 luxmeters have been chosen, particularly for their simplicity and price. Room 204 on the 3rd floor of the SH was chosen for the measurement. It is a room equipped with a lighting system controlled to a constant lighting level by means of components of the KNX bus system, when every room is equipped with a lighting sensor and 4 dimmer fluorescent lights Thorn Jupiter2 (2x28W) (Fig. 2). In room 204, the model was verified for the prediction of savings in lighting systems from the data measured. To compare the measured and calculated values, values were used as measured at a uniformly overcast sky and the measured lighting level of the outdoor unshaded plane of approx. 5000lx. Simultaneously with the comparison of measured and modelled values of daylight, the dimming of the artificial lighting system to a constant lighting level was verified on the sensor in the middle of the room (Fig. 4), (Valicek (2015).

3. SYSTEM DESCRIPTION – OPERATIONAL MEASUREMENT

For lighting control, KNX technology is used. The KNX technology in SH is aptly integrated in the BACnet technology by means of an interface with the ensuring of interoperability between communication protocols. Control visualization and regulation of the operating technology functions in the building (lighting, HVAC, blinds…) and the saving of the measured data has been created by means of the Desigo Insight SW tool. The lighting control to a constant lighting level by means of the KNX technology with a closed control loop is based on the lighting level modulation inside the room in the SH by the measuring of the outdoor (autonomous variable (E_{knxout})) lighting with an outdoor KNX sensor as well as the feedback to the indoor lighting level (dependent variable (E_{knxin})) by means of an indoor KNX sensor in the room involving changes proportional to the outdoor lighting. The required lighting level at the place of the visual task is measured as a controlled variable. The controlled variable is increased by the interference value of lighting caused by the daylight component; then it is brought back to the KNX actuator within the control loop. The control system to constant lighting level in a single room in the SH includes (Fig. 4):

- Bus button (Push Button 4-f UP 245 DELTA) for switching on/off the lighting and switching over the automatic lighting mode and manual lighting mode in the room;
- Brightness Controller UP 255/11, (E_{knxin}),
- KNX/DALI Gateway N 141/02.

For the measurement of the outdoor lighting level (E_{knxout}) for operational purposes, a weather station is used, located on the house roof (Weather station GPS AP 257/22).

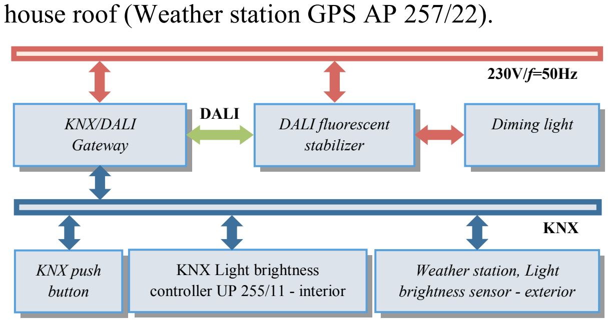

Fig. 4. Block diagram of lights control with using of the KNX components - system KNX/DALI Gateway.