Supervisory control using EIB – KONNEX technology: A sensor network protocol enabling a holistic and environmental approach in architecture.

John K. Sakellaris
Mechanics Sector
Faculty of Applied Mathematics and Physics
National Technical University of Athens
9, Iroon Polytecnioi street, 157 73 Zografou
GREECE

Abstract: - Firstly, the conceptual framework is described. This is the set of ideas and design approaches which it is believed to be fundamental to designing for sustainability in the built environment, and which will structure the value system for carrying out the research. This paper describes experiences drawn from real sensor network deployments, and large-scale simulation experiments, taken from a specific environmental field: that of energy management in an intelligent building, which gives satisfactory results in energy saving and hence improving environmental conditions, given that CO₂ emissions are reduced when using this technology. Then, a second part will follow, which concerns an analytic presentation of a small part of the project: the use of supervisory control of an intelligent building using EIB – KONNEX technology. This part of the paper describes the design and control methods for many aspects of energy consumption in a building, mainly lighting and heating / cooling, using the EIB / KONNEX technology. The basic objective is to present a modularly expandable and generally adaptable technology in order to progress from the stage of individually designed systems towards to wide range reliable integrated systems. It is shown that this technology provides the most reliable solution for controlling such systems, because of its standardization. Supervisory control and energy management of an intelligent building using EIB – KONNEX technology can be sent by the exploitation of EIB Power Line Communication. Finally, an energy saving of 50% can be achieved by using this technology.

Key-Words: - Supervisory control; Energy management; Intelligent building; EIB – KONNEX technology; Heat pump; Investment pay back period; Holistic approach; Ecology; Architecture; Built Environment; Sensor networks.

1 An introduction to holism
Holism (from ὅλος holos, a Greek word meaning all, entire, total) is the idea that all the properties of a given system (biological, chemical, social, economic, mental, linguistic, etc.) cannot be determined or explained by the sum of its component parts alone. Instead, the system as a whole determines in an important way how the parts behave.

The general principle of holism was concisely summarized by Aristotle in the Metaphysics: "The whole is more than the sum of its parts."

Reductionism is sometimes seen as the opposite of holism. Reductionism in science says that a complex system can be explained by reduction to its fundamental parts. Essentially, chemistry is reducible to physics, biology is reducible to chemistry and physics, psychology and sociology are reducible to biology, etc. Some other proponents of reductionism, however, think that holism is the opposite only of greedy reductionism.

On the other hand, holism and reductionism can also be regarded as complementary viewpoints, in which case they both would be needed to get a proper account of a given system.

1.1 Holism in architecture and industrial design
Architecture and industrial design are often seen as
enterprises, which constitute a whole, or to put it another way, design is often argued to be a holistic enterprise [1]. In architecture and industrial design holism tends to imply an all-inclusive design perspective, which is often regarded as somewhat exclusive to the two design professions. Holism is often considered as something that sets architects and industrial designers apart from other professions that participate in design projects. This view is supported and advocated by practising designers and design scholars alike, who often argue that architecture and/or industrial design have a distinct holistic character.

Holistic architecture can be defined as built environments that are harmonious with their universe, and prosperous to their inhabitants. To build holistically is to work with material, form, meaning and energy to celebrate and respect the miracle of the created lives, and to help people individually and collectively to achieve their highest potential.

Holistic architecture is a comprehensive and highly-integrated approach towards the making of places. A holistic architecture firm offers the same high level of expertise of other architectural design firms, plus a range of additional skills and services that are essential to the creation of a superb environment.

The paradox of holistic architecture is that while many of its underlying philosophies come from ancient sources, it has only recently emerged as a professional design option in today’s building industry. It has been said that every thing happens in its proper time and place. The world today is full of promise and wonder, yet also filled with unprecedented challenges. In order to rise above these challenges the best of ancient and modern worlds must be used together to move to a better reality.

The environments inhabited in day to day lives have a huge affect on people physical, spiritual and energetic selves. The positive influences of holistic architecture support people to attain to highest and best purpose, and contribute to joy and success in all things. As such, it offers to the people a powerful means of improving their own lives, and the universe they live in.

2 On the notion of the Environmental Sensor Network

An Environmental Sensor Network (ESN) comprises of an array of sensors that gathers data autonomously and forwards them automatically to a central server. What differentiates modern sensor networks from previous techniques is an emphasis on intelligence in the sensors as well as in the data network.

Modern sensor networks also typically publish the data on the server on the World Wide Web and allow real-time access to the data. These networks require a unique combination of technological and environmental understanding, and have the potential to create a revolution in environmental monitoring.

Different types of data are collected by the sensor nodes. These data can be in different forms: digital and analogue, spatial and temporal, database or image, fixed or moving. At the server level, the data can be visualised and analysed within a Geographic Information System (GIS), combined with a satellite image and/or map, and published via the Web to give researchers seamless access to information.

ESNs have the capability of capturing local and broadly-dispersed information simultaneously; they also have the capacity to respond to sudden changes in a location by triggering observations selectively across the network while simultaneously updating the underlying complex system model and/or reconfiguring the network.

Data gathered by ESNs pose unique challenges for environmental modelling, as a complex system is being observed by a dynamical network. These challenges lie in the fields of computer science (from self-organising networks to algorithm analysis), mathematics (from computational geometry to data fusion and robotics), and statistics (from sampling design to prediction and prediction uncertainty).

This paper describes experiences drawn from real sensor network deployments, and large-scale simulation experiments, taken from a specific environmental field: that of energy management in an intelligent building, which gives satisfactory results in energy saving and hence improving environmental conditions, given that CO₂ emissions are reduced, when using this technology.

3 From the general to the specific – The case of Supervisory control of an intelligent building using EIB – KONNEX technology

3.1 An introduction to the concept of intelligent building and EIB– KONNEX technology

The concept of an intelligent building is, and will probably remain, ill-defined. In its most
general sense it should mean a building that in some way can sense its environment, reach decisions about the state of that environment and communicate those decisions. In practice this should mean that a building can adjust some aspect of the interior or exterior environment in response to a change in some other aspect of that environment.

As trends in modern residential building construction tend to energy conservation and higher efficiency, the passive solar airtight home (R2000 in Canada) is fast becoming a standard. One such home is analyzed in [3] using a two-year set of measurements from a high temporal resolution data logging station. The overall energy-conserving performance of the home is determined and related to other previous structures. Short-term effects are investigated with a view to relating them with owner/operator control of the home's air-handling systems. It is found that in these structures, setback thermostats may be counterproductive and manual de-humidistat control leads to a complex set of interactions much beyond the scope of even knowledgeable home owners to predict. This suggests the requirement for intelligent automated control of residential air-handling systems.

Another study [4] deals with two methods for modelling and estimating the daily and annual variation of soil surface temperature. Soil surface temperature is an important factor for calculating the thermal performance of buildings in direct contact with the soil as well as for predicting the efficiency of earth-to-air heat exchangers. The two estimation methods are a deterministic model and a neural network approach. The two methods are tested and validated against extensive sets of measurements for bare and short-grass covered soil in Athens and Dublin. Finally, the comparison of the two models showed that the proposed intelligent technique is able to adequately estimate the soil surface temperature distribution. This work can be incorporated in a Decision Support System handling energy management of an intelligent building.

A new approach for short-term load prediction in buildings is shown in [5]. The method is based on a special kind of artificial neural network (ANN), which feeds back a part of its outputs. This ANN is trained by means of a hybrid algorithm. The new system uses current and forecasted values of temperature, the current load and the hour and the day as inputs. The performance of this predictor was evaluated using real data and results from international contests. The achieved results demonstrate the high precision reached with this system. This work can be incorporated in a Decision Support System handling energy management of an intelligent building too.

Another study [6] presents a multi-criteria decision-making model for lifespan energy efficiency assessment of intelligent buildings (IBs). The decision-making model called IBAssessor is developed using an analytic network process (ANP) method and a set of lifespan performance indicators for IBs selected by a new quantitative approach called energy-time consumption index (ETI). In order to improve the quality of decision-making, the authors of this paper make use of previous research achievements including a lifespan sustainable business model, the Asian IB Index, and a number of relevant publications. Practitioners can use the IBAssessor ANP model at different stages of an IB lifespan for either engineering or business oriented assessments. Finally, this paper presents an experimental case study to demonstrate how to use IBAssessor ANP model to solve real-world design tasks.

In this paper another strategy is adopted for energy management in intelligent buildings. It uses the EIB building installation technology [7]. EIB is an innovative building installation technology ("bus system") which has been promoted since 1990 by the EIBA group of manufacturers (EIB association) which has its headquarters in Brussels. EIBA is involved with issuing trademarks, testing and quality standards, standardization and marketing activities. The flexibility and modularity of European Installation Bus (EIB / KONNEX) [8] technology using twisted pairs, power lines and radio frequency media in combination with the availability of compatible components by a growing number of large manufactures are some of its major assets.

Various methods have been developed in facing the traffic congestion in domestic networks so far. However, all these methods can be applied through the EIB / KONNEX technology. Especially, compatibility is achieved by using EIB / KONNEX standard interfaces. The advantages of this solution are high reliability, simple expandability as well as simple installation, use and maintenance. Furthermore, exploiting the communication via power lines, a low cost energy management for
lightning can be integrated in it, achieving significant energy saving by using dimming scenarios at certain time periods. The advantages of EIB are:
- Increased safety,
- Economic use of energy during the operation of buildings,
- Simple adaptation of the electrical installation to the changing requirements of the user,
- Higher degree of convenience.

The above arguments are evaluated differently from the point of view of the client or the user of the installation e.g. functional building compared to residential building, able-bodied people compared to disabled people, young people compared to elderly people. Devices from different manufacturers and functional areas that are supplied with the EIB trademark can easily be linked to form a functioning EIB installation.

Devices from different manufacturers and functional areas that are supplied with the EIB trademark can easily be linked to form a functioning EIB installation.

3.2 Communication
3.2.1 Basic Method of Operation
A minimum TP EIB installation consists of the following components:
- a power supply unit (24V DC),
- a choke (can also be integrated in the power supply unit),
- sensors (a single switch sensor is represented in the graphic above),
- actuators (a single switch actuator is represented in the graphic above) and
- a bus cable (only twin core is required).

3.2.2 Useful Data Telegram
In principle a distinction is made in the data between the commands. The data is shown here using the example of a 1-bit telegram. In the case of the “write” command the last bit on the right contains a “1” or a “0” for “Switch on” or “Switch off”. The “read” command requests the addressed bus device to report its status.
The reply may be a 1-bit message as in the example of the “write” command, or it can use up to 13 bytes (bytes 2 to 15). The length of the data is dependent on the EIS type in use.

### 2.2.3 Cable Lengths

Within a bus line, the following cable lengths are permitted:
- Power Supply Unit - Bus device: 700 m
- Bus device - Bus device: 350 m
- Total bus line length: 1000 m
- Minimum distance between 2 power supply units on one line: 200 m

### 3.3 Topology

#### 3.3.1 Topology Line

Each bus device (DVC) can exchange information with any other device by means of telegrams. One line consists of a maximum of 4 line segments, each with a maximum of 64 bus devices. Each segment requires an appropriate power supply. The actual number of devices is dependent on the power supply selected and the power input of the individual devices.

#### 3.3.2 Topology Area

If more than 1 line is to be used or if a different structure is to be selected, then up to 15 lines can be connected to a main line via a line coupler (LC). This is called an area. It is also possible to have up to 64 bus devices on the main line. The maximum number of bus devices on the main line decreases by the number of line couplers in use. Each line, including the main line, must have its own power supply unit. Line repeaters may not be used on backbone or main lines.

#### 3.3.3 Topology: Several Areas

The installation bus can be expanded by means of a backbone line. The backbone coupler (BC) connects its area to the backbone line. It is also possible to have bus devices on the backbone line. The maximum number of bus devices on the backbone line decreases by the number of backbone couplers in use. Within a maximum of 15 functional areas, more than 64,000 bus devices can be connected to the bus system. By dividing the EIB installation into lines and areas, the functional reliability is increased considerably.
3.4 Telegram
When an event occurs (e.g. when a pushbutton is pressed), the bus device sends a telegram to the bus. The transmission starts after the bus has remained unoccupied for at least the time period t1. Once the transmission of the telegram is complete, the bus devices use the time t2 to check whether the telegram has been received correctly. All “addressed” bus devices acknowledge the receipt of the telegram simultaneously.

![Telegram Diagram](image)

Figure 6: Duration of telegram.

3.4.1. Telegram Structure
The telegram consists of bus-specific data and useful data which provide information about the event (e.g. pressing a push button in EIB). The information is transmitted in its entirety in the form of 8-bit long characters. Test data for the detection of transmission errors is also transferred in the telegram: this guarantees an extremely high level of transmission reliability.

![Telegram Structure Diagram](image)

Figure 7: Telegram structure.

The telegram is transmitted at a bit speed of 9600 bit/sec, i.e. one bit occupies the bus for 1/9600 sec or 104 µs. A switching telegram (including acknowledgement) occupies the bus for 20 ms. Telegrams for text transmission occupy the bus for up to 40 ms.

3.5 EIB BUS DEVICES

![EIB Bus Devices Diagram](image)

Figure 8: EUB bus devices.

3.5.1 Introduction to EIB BUS DEVICES
A functioning bus device (e.g. dimming actuator/drive control, multi-functional push button, fire sensor, …) principally consists of three parts:
- bus coupling unit (BCU)
- application module (AM)
- application program (AP)

Bus coupling units and application modules are offered on the market either separated or integrated into one housing. They must however be from the same manufacturer.

If separated, the application module is connected to the BCU via a standardised application interface, the Physical External Interface or PEI. This 10 or 12 pin PEI serves as an interface to exchange messages between both parts (5 pins)

- the power supply of the application module (2 pins)

When the BCU is an integrated part of the bus device, it has mostly been built into the bus device via a BIM (Bus Interface Module) or via an EIB chip set by the manufacturer of the bus device. Principally a BIM is derived from a bus coupling unit by omitting the latter's housing and a number of other components. An EIB chip set consists of the core of a BIM, i.e. the controller and the transceiver.

The BCU is currently available for connection to two different media: Twisted Pair (Safe Extra Low Voltage 32V) or Power-line (mains power). Connection to radio frequency networks and the infrared medium is currently under development.

Each bus device has its own intelligence owing to the integrated BCU: this is the reason why EIB is run as a decentralised system and does not need a central supervising unit (e.g. a...
computer). The central functions (e.g. supervision) can, however, if needed, be assumed by visualisation and control software installed on PCs. Bus devices can principally be divided into two classes: sensors and actuators. In the case of a sensor, the application module transfers information to the BCU. The latter codes this data and sends it on the bus. The BCU therefore checks the state of the application module at appropriate intervals. In the case of an actuator, the BCU receives telegrams from the bus, decodes them and passes on this information to the application module. An EIB bus device receives its specific function once the appropriate application program for the application module has been loaded into the (universal) BCU (in most cases this is done via the EIB Tool Software).

The TP transceiver has the following functions:
- Separation or superimposing of the direct current and data,
- Reverse voltage protection (RPP),
- Generation of stabilised voltages of 5 respectively 24V,
- Initiating a data back-up (U-save) if the bus voltage drops below 18V,
- Triggering a processor reset if the voltage drops below 4.5 V,
- Driver for transmitting and receiving,
- Sending and receiving logic.

3.5.3 Type Definition of an Application Module

Via a resistor (R-Type) in the application module, the bus coupling unit is able to detect via pin 6 of the PEI, whether a suitable application module has been mounted on the BCU.

3.5.4 Application Function: 'Dimming Actuator'

During the dimming period, the bus coupling unit increases or decreases the digital brightness value according to the set regulating time. The
brightness value is continuously passed on to the shift register (SR) in the application unit. The 8 bit long data word allows the generation of $2^8 = 256$ brightness values. The data word is fed into the digital/analogue converter (DAC), which then generates the appropriate control voltage in the range of 0 to 10V. The dimmer's electronic choke uses the voltage to control the light emission of a fluorescent tube. The power circuit breaker in the application unit is used to (dis)connect the mains voltage.

3.6 EIB POWERLINE
3.6.1 Introduction to EIB Power line
EIB Power line allows the transmission of telegrams across the 230/400 V network. A separate bus line is therefore not necessary. Telegram repetition takes place via external and neutral conductors which must be connected to every device. The system is compatible with EIB components and the corresponding tools. It is possible for instance to plug a flush-mounted application module onto a flush-mounted mains coupler and to load the application software via the 'bus cable' (230/400 V supply line) into the mains coupler. In spite of the undefined transmission characteristics of the energy supply system (caused by cable types, cable length, type and number of connected devices,…), EIB Power line ensures a high level of security during telegram transmission. The system works bi-directionally in a half-duplex operation i.e. every device can transmit and receive.

3.6.2 Standardisation
In Europe, signal transmission via the energy supply system is regulated by the CENELEC standard EN 50065. Part 1 of this standard defines general requirements, frequency ranges, transmission levels and requirements for electromagnetic compatibility (EMC). EIB Power line uses the frequencies 105.6 kHz and 115.2 kHz for transmission.

Due to the middle frequency of 110 kHz, the EIB Power line system is sometimes referred to as PL110. As the standard only allows a maximum transmission level of 116 dB µV, the devices are sometimes called 'class 116' devices.

3.6.3 Transmission Process
Owing to the continuous progress made in the miniaturisation of electronics, it was possible to apply a new transmission process for EIB Power line i.e. Spread Frequency Shift Keying or SFSK for short. It functions as follows:
If a ‘0’ is transmitted, the transmitter produces a frequency of 105.6 kHz and the supply voltage is superimposed.
If a ‘1’ is transmitted, a frequency of 115.2 kHz is used.
In order to ensure a safe transmission at the highest possible speed, the rate of 1200 bit/s is set in all mains couplers which corresponds to a bit duration of 833 µs.
All mains couplers are permanently in receive mode. A received signal (also noise) is permanently converted into a digital value. This digital value is now fed into two correlators (probability comparators) which compare the received digital value with a stored, digital frequency reference pattern.
There are two correlators in each mains coupler: one for the ‘0’ bit and one for the ‘1’ bit.
The correlators can differentiate with a calculable probability that:
- It is a ‘0’
- It is a ‘1’
- it is undefined (noise) and the bit is therefore rejected.

Figure 13: The transmission process.
The combination of bit patterns as well as specialised error detection methods allow a guaranteed level of telegram recognition. In addition, a further innovative technique is used, namely the permanent and automatic adaptation of transmission power and receiving sensitivity. This process allows continuous adaptation of the transmission power to the network.
characteristics, thereby taking into account that the maximum transmission level is never exceeded. All receivers likewise permanently control their sensitivity according to the network characteristics. This results in an optimum transmission range even under constantly changing supply conditions.

![Figure 14: Phase coupling.](image)

### 3.6.4 Phase Coupling
In order to ensure that data is transmitted on all three conductors, the following two possibilities exist:

- In smaller installations, a passive phase coupling across the connections to devices with more than one phase (e.g. gas heater, electric cooker) can suffice. However, in order to ensure a defined coupling between the three phases, the use of a phase coupler is recommended.
- In larger installations, the integration of a repeater is recommended. The repeater has 4 poles (3 external conductors and 1 neutral conductor) and couples signals with the highest possible transmission level on each external conductor.

Phase couplers and repeaters may not be installed simultaneously in an installation. This means that if a repeater is retrofitted in an installation with an integrated phase coupler, the phase coupler must be removed.

### 3.6.5 Telegram Transmission
Compared to the EIB-TP telegram, EIB Power line requires additional information during the transmission of data.

<table>
<thead>
<tr>
<th>Training sequence</th>
<th>Preamble field</th>
<th>Telegram as for EIB-TP</th>
<th>System ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 bits</td>
<td>2 x 8 bits</td>
<td>Variable length</td>
<td>8 bits</td>
</tr>
</tbody>
</table>

![Figure 15: Additional information included in the telegram due to EIB Power Line.](image)

#### 3.6.6 Training Sequence
The training sequence acts as the automatic reception adjustment of the receivers (thus of all mains couplers except those that are transmitting). The receivers adjust their reception to the network conditions.

#### 3.6.7 Preamble field
The preamble field has two functions:
- It marks the start of the transmission.
- It controls the bus access.

#### 3.6.8 Telegram
After this, the actual telegram is transmitted (as on EIB-TP), in which four additional bits of test data are added to every transmitted byte. With the help of this test data, one bit errors can be corrected and multi-bit errors can be detected.

#### 3.6.9 System ID
Each telegram is terminated by a field which contains the System ID. The System ID consists of 8 bits (with an additional 4 bits of test data) and can be set by the project engineer of the installation between 1 and 254. The System ID is reserved for information to all devices.

The objective of the System ID is to prevent EIB Power line installations that are positioned in close proximity from influencing each other. For this purpose, a distinct System ID is attributed to each EIB Power line installation.

As the System ID is transmitted in the telegram, each receiver can establish whether the telegram belongs to its installation and then react accordingly.
3.6.10 Reply Telegram
The reply telegram is produced as a result of the received telegram and must reach the transmitter after a certain period of time. Compared to EIB-TP, only two reply telegrams are transmitted:
- **ACK:** Transmission was successful.
- **NACK:** Transmission was not successful. This reply telegram is only used by the repeater.
If the reply telegram is not sent, the telegram is repeated. The further process is dependent on whether the system contains a repeater or not.

3.6.11 Bus Access Procedure
The collision problem has been resolved by the use of special time slots i.e. every mains coupler may only transmit during specified periods. However, if several mains couplers try to start transmission simultaneously, the following applies:
- The mains couplers detect a collision and determine a random priority for the transmission of telegrams.
- The mains couplers do not detect a collision and the telegrams are lost.

3.6.12 Topology / Addressing

The logical addressing of EIB-PL is compatible with EIB-TP. A maximum of 8 areas (compared to 15 for EIB-TP) can be addressed, each with 16 lines of 256 devices. Areas containing PL signals must be separated from the general supply system via band-stop filters. The media coupler forms the interface to EIB-TP in combined installations. In a detached house it is not strictly necessary to split up the devices into lines and areas via corresponding couplers, provided that the number of PL devices does not exceed 256. All PL devices can exchange data across all 3 phases via the 230 V installation network, as soon as a phase coupler or repeater has been installed.

In larger installations, the bus load is reduced via a logical and physical classification of the EIB-PL installation into a maximum of 8 areas (with up to 255 PL devices per area). The physical separation of the individual areas is achieved using band-stop filters. Data can be transmitted from one area to another via a separate data cable between the various backbone couplers. The active phase coupling on the PL side is carried out by the backbone coupler. The physical separation and the filter table of the backbone coupler allow a selective transmission of telegrams into the neighbouring area. The bus load in the entire system is thus considerably reduced.

3.7 Results
The aforementioned technology was applied to a building [9, 10].
The building is located in Athens, near the airport and consists of: an apartment in the first floor; an attic; a bookshop and a shop that sells desalination plants in the ground floor; and an office room with a DVD club in the basement. The EIB - KONNEX system has been installed in all the building for controlling the lighting and the heating/cooling system of each area. The conventional security system has been interfaced to EIB - KONNEX system for activation/deactivation of the heating/cooling system of every room.

Energy consumption was written down for every part of the building. The energy consumption for the bookshop follows.

A Supervisory Control and Data Acquisition (SCADA) monitors the bookshop energy & power consumptions, and all the inside and outside temperatures. It uses the EIB – KONNEX protocol for data acquisition. The SCADA acquires also the beam & diffuse solar radiation on horizontal level. The Finite Difference Calculation Method (FDC) has been programmed and operates in on-line mode under the SCADA. It gets data from the SCADA and in this way it performs numerical calculations concerning the modelled physical phenomena faster. An Energy Management System based on FDC has been implemented, achieving energy saving especially during summer with higher degree of convenience. Furthermore, lighting and heating/cooling control have been also integrated. The SCADA in co-operation with an ADSL line accomplish remote control and increase safety issuing web cameras video through Internet – SMS and Phone Call in the case of an alarm.

Figure 18: The building of application (Athens).

Lighting Control
Lighting control has been implemented in the bookshop and DVD Club as follow:

a) Bookshop
A Presence Detector, a dimmer for controlling digital electronic ballasts and a binary input for the connection of the conventional alarm system have been installed in the bookshop. When the bookshop is opened and a customer is inside it, the lights are controlled by the presence detector according the solar radiation in the bookshop. The brightness value of the presence detector is set by the user through the SCADA. The switch off time is set by the user via the proper potentiometer of the Presence Detector. When the bookshop is opened and no any customer is inside except the employee, the presence detector switch off the lights after a certain period, while at the same time the SCADA measures the outside solar radiation and dims the lights to a minimum brightness. This helps the customers outside the shop to realise that the shop is opened, while achieving energy savings.

When the bookshop is closed, the alarm system gives this information to the EIB - KONNEX. The SCADA exploits this information by the OPC Server, and when the outside solar radiation is above from a threshold, the lights are switched off, while in the opposite case (during night), they are dimmed to 10%. It is noted that the presence detector controls the lights independently if the bookshop is opened or closed or if it is day or night. Here, it should be mentioned that solar radiation and solar luminance are inherently related and it is solar luminance, which serves directly for the lighting control of this section of the building.

The quality of the lighting is increased...
considerably making both customers and employees to be impressive by this functionality. By using SCADA and EIB – KONNEX as protocol of data transmission to the SCADA the energy saving is more than 35%, and the pay back period is 1.9 years resulting energy savings 4,290KWh/year and saved 3,432 Kg CO₂/year.

Figure 21: Typical solar radiation profile.

b) DVD Club

A Presence Detector, a Binary output for switching On/Off the electronic ballasts and a binary input for the connection of the conventional alarm system have been installed in the DVD Club. The DVD Club is in the basement and so the solar radiation which comes inside the shop is not considerably enough in order to use dimming control. Here, it should be mentioned that solar radiation and solar luminance are inherently related and it is solar luminance, which serves directly for the lighting control of this section of the building.

When the presence detector is activated by a customer the lights are switched On and, when there is not any customer but only the employee, or when the DVD Club is closed the lights are switched off after a certain time. The switch off time is set by the user via the proper potentiometer of the Presence Detector.

By using SCADA and EIB – KONNEX as protocol of data transmission to the SCADA the energy saving is more than 40% by this functionality as it is depicted in the figure below and the pay back period is 3.9 years resulting energy savings 1,284KWh/year and saved 1,028 Kg CO₂/year. Other trends of energy consumption, showing a baseline, may be found in [11].

Figure 22: DVD Lighting Consumption

Heating and ventilation Control

Every heat pump in the corresponding room for heating/cooling operation is controlled through EIB - KONNEX devices. A thermostat, a binary output for switching on/off the heat pumps and binary input for the connection of the conventional alarm system have been installed in every room. In the most cases the thermostat has been programmed so that the range of the setpoint to be from 18 until 21 degrees centigrade during winter and from 24 until 27 degrees centigrade during summer. By taking into account that for a temperature change from e.g. 21 to 20 degrees centigrade, the energy savings are up to 10%, therefore more than 10% is achieved by this functionality.

Furthermore, during normal operation of the building, the heating/cooling system is switched off in the corresponding area, when a window or a door opens for a certain time. This information is received by the conventional alarm system through the corresponding binary input. The monitored measurements from the SCADA, by using this strategy, proved energy savings of about 20%.

The SCADA using the Finite Difference Calculation Method (FDC) evaluates the efficiency of the heat pumps. The efficiency of a heat pump can be evaluated directly from measurements of the compressor power and the flow and temperature difference of the recirculating air. The Finite Difference Calculation Method (FDC) has been programmed and operates in on-line mode under the SCADA. It gets data from the SCADA and in this way it performs numerical calculations concerning the modelled physical phenomena faster. An Energy Management System based on FDC has been implemented, achieving energy saving especially during summer with higher degree of convenience. On the other hand the efficiency of the insulations of the building is monitored continuously and the repair can be made at the right time. For this reason, the SCADA issues
an Alarm to the user informed him that should maintain the heat pumps or the wall insulations. The control of this can result energy savings of more than 50% when the maintenance is accomplished at the right time. By using SCADA and EIB – KONNEX as protocol of data transmission to the SCADA the total energy saving by this functionality in the Bookshop is about 35%, and the pay back period is 6.8 years resulting energy savings 1,470KWh/year and saved 1,176 Kg CO$_2$/year. However it could be more than 50% exploiting the FDC method for the maintenance of the heat pumps at the right time. Other trends of energy consumption, showing a baseline, may be found in [11].

Figure 23: Typical bookshop daily load profile and heat pump consumption.

In the DVD Club there is a ventilation system where it cleans the air from a smoke pollution. Usually, the employee used to switch on this, forgetting to switch off after some period. By using a push button and a properly programmed binary output, when the ventilation system is switched on it will be switched off after 10 minutes resulting considerably energy savings.

4 Conclusion

Firstly, the conceptual framework was described. This is the set of ideas and design approaches which it is believed to be fundamental to designing for sustainability in the built environment, and which structured the value system for carrying out the research. Then, a second part followed, which concerns an analytic presentation of a small part of the project: the use of supervisory control of an intelligent building using EIB – KONNEX technology. In this part of the paper the advantages of the European Installation Bus (EIB / KONNEX) Technology are presented for supervisory control and energy management of an intelligent building using EIB – KONNEX technology. It is shown that this technology provides the most reliable solution for controlling such systems, because of its standardization. Furthermore, the communication through OPC Server makes possible the supervisory control and energy management of an intelligent building using EIB – KONNEX technology via several Visualization Software packages. Supervisory control and energy management of an intelligent building using EIB – KONNEX technology can be sent by the exploitation of EIB Power Line Communication. Finally, an energy saving of 50% can be achieved by using this technology.

References:
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