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ADVANCED DECISION SUPPORT TECHNIQUES IN COMBINATION WITH SMART CARD AND LOCAL OPERATING NETWORK TECHNOLOGIES FOR INTELLIGENT ENERGY MANAGEMENT IN BUILDINGS

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ABSTRACT

The purpose of the present paper is to present recent developments of integrated building energy management system combining intelligent decision making systems and smart card technology using Local Operating Network (LON) techniques applying mainly to existing buildings and to new buildings with minimum construction modifications. The development of the above Integrated Energy Management System (IBEMS) is focusing on 25% energy savings at existing buildings comparing to conventional control systems improving at the same time the indoor conditions and comfort. The project is funded in part by the European Commission in the framework of the Non Nuclear Energy Program **JOULE III (CT97-0044)**

1. INTRODUCTION

One of the main disadvantages of the existing BEMS is that in order to be integrated in existing buildings a great number of modifications are required.

The purpose of the present paper is to present the architecture and the offering capabilities of an Intelligent Building Energy Management System (IBEMS) which is in the process of development under the framework of the Joule III European Commission Project CT-970044 BUILTECH system.

2.SYSTEM'S GENERAL DESCRIPTION

. The IBEMS development consists from the following parts:

- Development of a global fuzzy rule based decision support system.
- Development of the generic method using adaptation and self learning techniques aiming to adapt in real time the global decision making system.
- Integration of smart card for occupants access to the building services offering an active man machine interface.
- Development of an advanced PLC (Programmable Language Controller) easy to install and operate especially in existing buildings and able to execute the fuzzy rules of the decision making system in real time.
- The Local Operating Network (LON), for data transmission throughout the building, in order to complete the hardware development.

The architecture of the IBEMS (Intelligent Building Energy Management System) can be seen in the figure 2.1.

3. THE ROLE OF THE PLC CONTROLLER

The prototype PLC based controller consists from a Central Unit that includes the power supply, the CPU module and a number of digital and analog Input /Output ports.

Every module includes its individual processor for the I/O implementation, the diagnostics generation and the data interchange to and from the Central Unit.

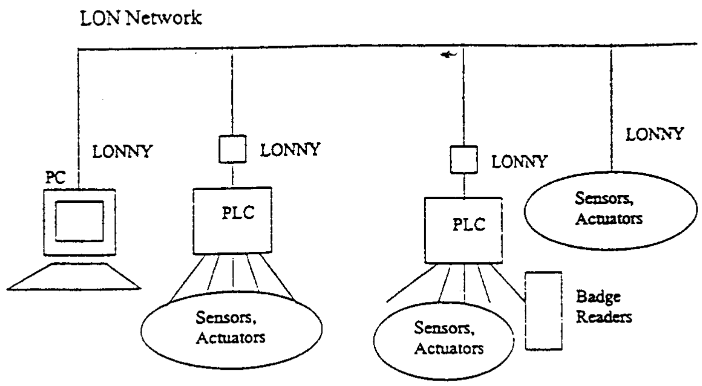

Figure 2.1.

The PLC controller which can be seen in figure 3.1. includes the fuzzy decision making system that aims to improve the indoor comfort and in parallel to minimize the energy consumption. The inputs to the fuzzy PLC controller are the environmental parameters that are monitored through the system's sensors:

- Dry bulb temperature
- Mean radiant temperature
- Relative humidity
- Air velocity
- Indoor illuminance
- Outdoor illuminance
- Luminance of task, background and source areas
- CO_2 levels
- Total Volatile Organic Compounds (TVOC) levels

Those inputs are used for the estimation of the controlled parameters of the fuzzy controller, which are:

- The Predicted Mean Vote (PMV)
- The Illuminance levels (ILL)
- Daylight Glare Index (DGI)
- CO_2 levels
- (TVOC) levels

The controlled parameters form the inputs of the fuzzy "if … then" rule base expert system that aims to improve the indoor conditions of the building and minimize the energy consumption. The fuzzy algorithms are giving priority to the use of renewable energy sources as well as passive techniques to improve the indoor conditions. The fuzzy algorithms are developing and been tested under MATLAB/ SIMULINK. The model of the building zone and fuzzy controller can be seen in figure 3.2. The system's outputs (actuators) depend on the experimental buildings characteristics and facilities.

Five existing buildings have been already selected for the integration and experimental action of the IBEMS. Since the educational and office buildings are characterized by high energy consumption, three offices and two educational buildings in different climatic zones throughout Europe are selected for the implementation and testing of the developed IBEMS.

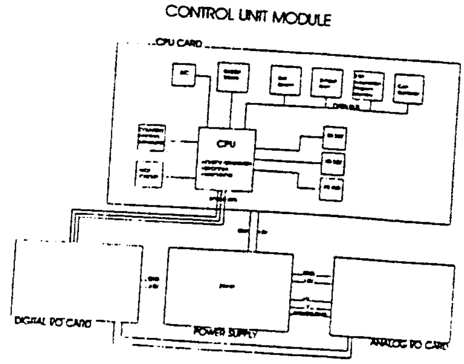

Figure 3.1.

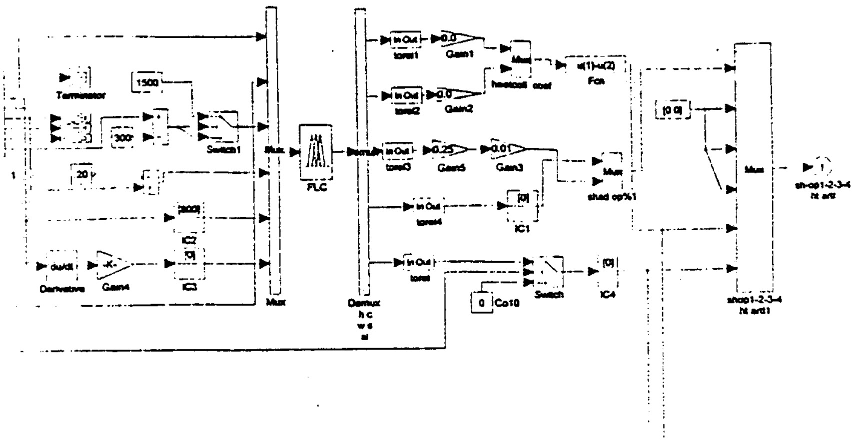

Figure 3.2

4. THE ROLE OF THE SMART CARD SYSTEM

The smart card system consists from the autonomous terminal and the smart cards, which are the chip cards.

The smart card system is suggested as the interface between the users and the building services (PLC, Central PC etc.) and it is the system's Man Machine Interface. The architecture of the smart card system can be seen in figure 4.1.

It combines the following parts:

- ✓ The motherboard connected with the smart card reader, the keyboard display and the PLC.
- ✓ The keyboard and the text / graphic display which appear with the keyboard display unit.

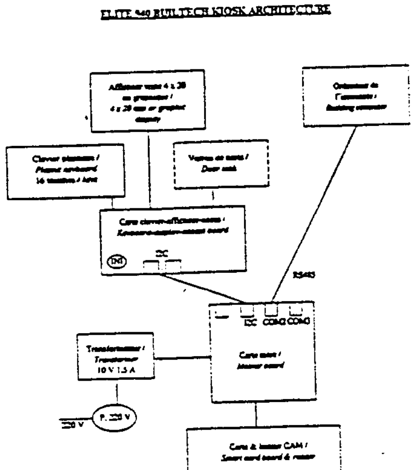

Figure 4.1.

The role of the smart card system is described below:

- The smart card system acts as an occupant presence sensor. Every time the smart card is inserted in the system the area is considered as occupied. This means that when the smart card chip enters the terminal the building services (lighting, heating, cooling, and ventilation) start up through a message sent to the zone's PLCs. The aim is after a period of time the system starts automatically half hour before the average arrival hour of the users.
- As mentioned above the smart card system is inserted as the man machine interface. Therefore its aim is by getting people involved in the process of the building energy use,

to become more energy conscious and increases the energy awareness. This is accomplished by:

The users through the smart card terminal can insert their thermal, visual and air quality preferences. Since it was really impossible for the users to type the level of the environmental parameters preferred (such as temperature: 21 °C, humidity: 60%, lighting: 300 lux) the users have the ability to set their preferences in a relative form. This implies that they can 'ask' for more or less heat/cool, more or less fresh air, more or less light. The preferences appear in the screen in the form shown in figure 4.2.

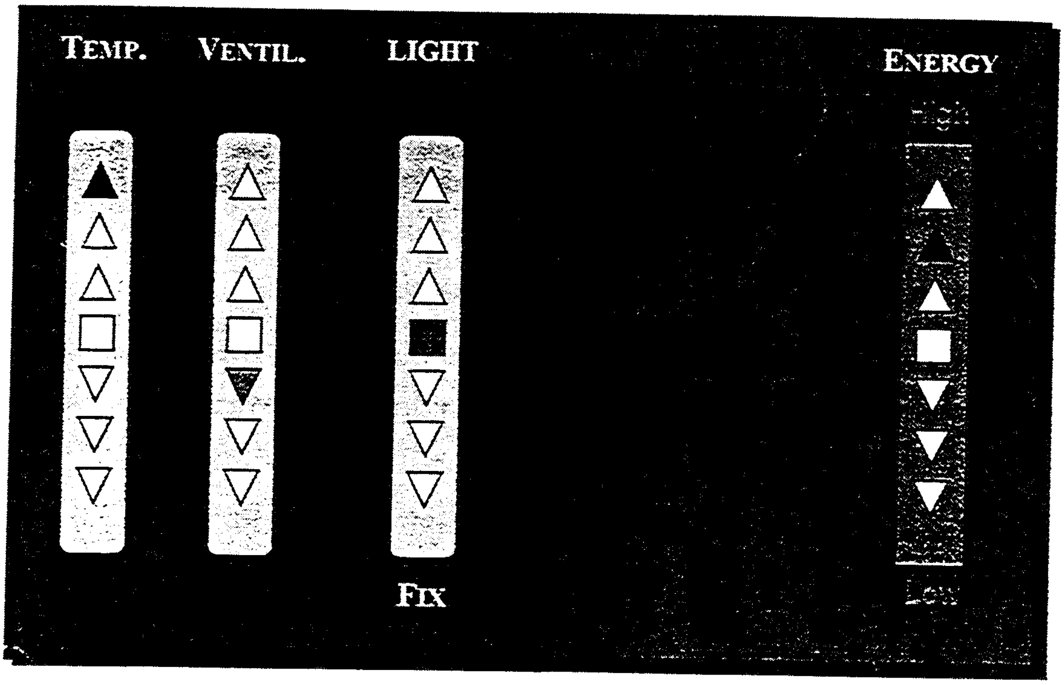

Figure 4.2.

Another role that the smart card system has to play is to send messages to the users through the terminal in order to increase awareness.
The messages sent can be seen in figure 4.2. The 'FIX' button allows the user to fix the lighting manually in case no electric or daylighting is needed (e.g. conferences, presentations).
All the above text messages are sent through the LON network (described in section 5) from the PLCs.
The data preferences are sent to the PLC where are evaluated so the controller to be able to understand the occupants preferences and adapt the fuzzy rule base expert system to users needs.

5. THE LOCAL OPERATING NETWORK

The connection and transmission of data of the described system is achieved by the Local Operating Network.
The diagram of an automated building offering the maximum degree of flexibility and expandability is shown in figure 5.1.
In figure 5.1 we can see that each input (sensor) is assigned to an actuator (output) by a software.
The data transmission throughout the system is achieved by the Local Operating Network system. The hardware of the system is then fully connected. The LONWORKS and LONTALKS combination of the LON ECHELON Inventor Company provide a worldwide protocol with interoperability and interchangeability properties.
A LONWORKS network consists from a number of nodes communicating over one or more media using a common protocol. The main parts of the network are:

- The Neuron Chip, which contains the communication protocol ensuring nodes interoperation.
- Transceivers (TP, Power lines, IR, RF, FO).
- Network equipment (Router, Repeater, Gateway, and PC cards, Router/Modem).
- PC or microprocessor communications software (DDE or MIP).
- Configuration, supervision and maintenance software.

The LON Network is an application suitable for buildings control due to the opportunities that it offers. More specifically the LONTALK protocol has been designed for applications involving sense, monitor, control and identification functions.:

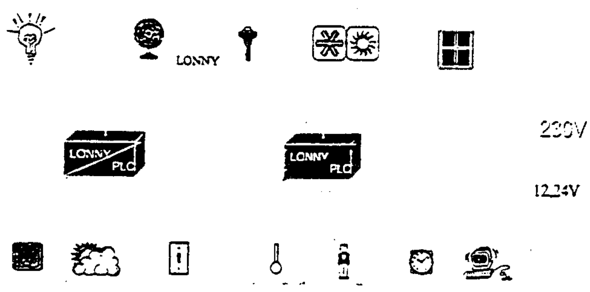

Figure 5.1

- The Lon networks offers free topology (ring, bus or star and all the combinations of the above).
- The LONTALK protocol supports end-to-end acknowledgments with automatic retries. When this service is used, a node sending a message will expect an acknowledgment from all intended receivers and will automatically retransmit the message unless all intended receivers respond. Absence of an acknowledgment, or a "heartbeat", can be used to trigger an alarm condition.
- Many LON nodes are small, simple devices: light switches, temperature sensors, on-off controls, etc. Such devices cannot tolerate substantial increases in size and cost. The LonTalk protocol has been designed for implementation using a single, low-cost, VLSI chip that can be economically and practically incorporated in these low-cost devices.
- The nodes used are "intelligent ones.
- The LonTalk protocol allows to choose the packet length on the basis of the application instead of divide the packets into subpackets. This is very useful concerning building switches, sensors and actuators because due to their variety of function and use different (4 to 25 bytes) packet length is produced.
- The LONTALK protocol supports communications on a variety of wired and wireless media, including:

  - Twisted pair
  - Power line (powered or unpowered)
  - Radio frequency
  - Coaxial cabling
  - Fiber optics

and for applications to buildings, the buildings power lines are used and no modifications are necessary for the application. Therefore the IBEMS can be installed in existing buildings where the energy use is high.

- Concerning media access, if priority is the only criterion for accessing the network, lower priority nodes can be completely starved out by more talkative ones. The LonTalk protocol allows a mixing of democratic media access (collision avoidance, resolution, and detection) with optional selection of priority.
- The LonTalk protocol provides the opportunity to bind network variables, together with the possibility to poll them.
- A great number of manufacturers exist that support any kind of application of the LON networks including buildings.

6. CONCLUSIONS

The described IBEMS integrates an intelligent fuzzy rule based controller with a Man Machine Interface in a "smart network". The energy saving is ensured by the fuzzy decision making system, while the users and their perception of comfort is the dynamic part of the system. The LON network provides the alternative of applying the IBEMS to existing buildings where the energy consumption is high and the cost of construction modifications to achieve minimization of energy use would be the only solution.

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