Image based Wireless Networked Lighting Control for Daylight–Artificial light Integrated scheme – A Literature Review

Susan G Varghese, Dr.Ciji Pearl Kurian , and Dr.V I George

***Abstract*—**Daylight artificial light Integrated schemes encompassing soft computing models have been perceived as a lucrative option for lighting energy conservation .This paper is a research proposal and the supporting literature review for the design and real time implementation of adaptive predictive control strategy for robust control of daylight artificial light integrated scheme. The model is proposed for supplementing the daylight with artificial light to meet the set point illuminance, maximizing the visual comfort by controlling the daylight glare, and for retaining the illuminance uniformity in the interior.

***Keywords*—**Image sensor, Lighting control, Zigbee, Field programmable gate array, Daylight –Artificial light integration.

I. Introduction

A new technology for the future to have fully automated adaptive lighting system for buildings with user comforts and safety is introduced in this review. In commercial buildings, air-conditioning and artificial lighting accounts for the majority of total energy consumption [1]. Though lighting represents about 17.5% of all global electricity consumption [2] only a small percentage of lighting in commercial buildings is controlled by anything other than an on/off switch. Even now in most of the buildings side lit windows are the only means of letting in daylight and warmth into the buildings [3].Daylighting in a building requires careful planning to balance heat gain and loss depending on climatic conditions, control glare, illuminance uniformity and adjustment for variations in daylight availability [4]. Intelligent lighting controls enable the lighting system to react to the actual conditions in space. With the lighting system, the user sets a target illuminance, and the system can automatically determine the necessary lighting, without making the user aware of the location of lights. Increasing the use of lighting controls would be a way of improving the energy efficiency of lighting systems. In addition to reduction of energy consumption, there is recognition that lighting control systems can contribute to green building certifications [5].Wireless technologies are providing options for implementing lighting controls in buildings where installing wired systems are impractical, and which will be centrally controlled, enabling them to be connected to the energy management systems. The proposed research work focuses on networking and automation of lighting control. In this research proposal Zigbee based wireless intelligent building lighting control system is proposed where the device discovery mechanism also is addressed. Zigbee is the most sought-after wireless technology in small operating areas like open plan offices and building automation [10].

Susan G Varghese, Assistant professor, Manipal Institute of Technology,Manipal,India (phone: 09980783317 ; e-mail:susgvarghese@gmail.com).

Dr. Ciji Pearl Kurian, Professor,Manipal Institute of Technology,Manipal,India (phone: 9740475127 ; e-mail:cpk001@yahoo.come@gmail.com).

Dr. V I Georg, Director of Electrical Sciences, Manipal university,Jaipur,India (phone:9448548101 ; e-mail:vig_rect@yahoo.com).

II. Literature Review

A. Camera as sensor in lighting control

Some of the sensors used in the lighting control systems are Photosensors, Occupancy sensors, Infrared sensors, Image sensors etc [3,4]. An Image sensor is a device that converts an optical image into an electrical signal. It is used mostly in digital cameras. A single camera sensor has the potential to replace the multiple sensors required by conventional systems for daylight harvesting, shading control, and occupancy sensing [13, 27]. The luminance can be calculated with the camera’s digital RGB output values by using the exposure value[32]. High Dynamic Range photography is a useful luminance measurement tool but relies on the camera and lens used and photometric calibration for its accuracy[31]. Newsham G R and Arsenault C D [13] demonstrated that a single Complementary Metal Oxide Semiconductor (CMOS) camera chip can replace the multiple sensors required by conventional systems for daylight harvesting, shading control and occupancy sensing.

B. Lighting control technologies

Lighting controls are important because they can eliminate wasted lighting energy in buildings while enhancing occupant comfort, productivity and security. Some of the lighting control technologies include:

i) Occupancy sensors:

Occupancy sensors use a variety of technologies to detect occupants and send appropriate signals to area lighting. Different methods of occupancy sensing are a) Passive

Infrared (PIR) technology b) Ultrasonic technology c) Dual technology and d) Acoustic detection: -

ii) Time switches: - These are mechanical or electronic devices which turn lights on or off after a specified interval.

iii) Photosensitive controls:-

This technology incorporates sensing of natural light to adjust the level of artificial lighting, based on the adequacy of the available natural light. The decision point will be whether the daylight harvesting control system should be closed versus open loop[5,8].

System components: - The photo-electrically controlled lighting systems consist of three basic components. 1.A photosensor for measuring the light level within or entering the controlled building space. The photosensor is assumed to have a photopic spectral response.2. A controller that incorporates an algorithm to process the signal to the dimming unit.3. A dimming unit that smoothly varies the light output of the electric lights by altering the amount of power flowing to the lamps.

iv)Lighting control panel systems: -

Facilitates managers achieve long term scheduled control through the use of lighting control panels. Load Scheduling control is automatically turn off lighting at the end of normal operating hours when the space is predictably unoccupied. Switching of lighting loads occurs at preset times with load scheduling. According to California Energy Commission 5 to 10% energy savings could achieve by load scheduling[11].

v) Remote/ Dimming controls:-

For personal control of work areas, users can choose remote controls that switch lighting on, off or dim light levels. Manual dimming is driven by visual/aesthetic needs .Automatic dimming used to realize a range of strategies is driven by energy cost savings and enables automatic changes in light level without irritating occupants. Manual dimming provides flexibility to select light levels required for different uses of the space. Using personal dimming occupants in private and open offices can be given the ability to select light levels based on need or preference. Step dimming provides a limited choice of light levels, with one or more preset increments between off and full output. Continuous dimming enables users to raise and lower light levels over a specified range, with smooth transitions between levels.

Bodart M and De Herde [14] evaluated by simulation the impact of lighting management as a function of daylight availability in office buildings of Belgium.The results show an annual energy saving of 35% to 45% depending on the window orientation and glazing transmittance. Yaning Wang and Zhaofeng Wang [16] emphasize on the system with several sensors for measuring temperature, lighting, number of people in the room and then the measured data to the coordinator node for a residential light control system. For integrated operation of blinds, electric lighting and HVAC is done by Guillemin A and Morel N [2] for the development and testing of user adaptive controllers. And the conclusion from the paper is due to the predictive ability of the controller the integrated scheme could save 25% energy consumption for duration of 94 days.

In daylight artificial light integrated scheme, for optimizing visual comfort, thermal comfort and energy consumption C P Kurian and R S Aithal [9] proposed a fuzzy logic based automated window blind controller suitable for tropical climate. The paper describes the results of three computational model suitable for the optimum integration of visual comfort, thermal comfort and energy consumption in schemes where daylight and artificial light are integrated. A simulink environment is established for the real time control and analysis of daylight-artificial light integrated schemes. The paper concludes that ANFIS diming with fuzzy logic based blind scheme optimises occupant comfort and energy saving. This scheme made use of the benefits of hybridization between simulation and machine learning for the purpose of light control. The work done by Sheryl G Colaco[4] exploits the concept of design and real time implementation of adaptive control strategy for control of daylight –artificial light integrated scheme. To elicit daylight variations, occupancy detections, and user preferences an online self-adaptive control algorithm is structured for real time control of artificial lights and window blinds. The developed model resolves the constraints of: i)supplementing the daylight with artificial light to meet the set point illuminance ii)minimizing the energy consumption iii)maximizing the visual comfort by controlling the daylight glare and iv)retaining the illuminance uniformity in the interior. A PC based wired real time control strategy for automated control of artificial lights and window blinds has been done by Sheryl G Colaco [4]. Wireless sensors and actuators have not been included in the scheme.

Ghisi E and Tinker J A [17] presented a methodology to predict the potential for energy savings on lighting using an ideal window area concept when there is effective daylight integration with the artificial lighting systems. According to the authors, ideal window area is the one in which there is an ideal balance between daylight provision and solar thermal load there by energy consumption due to artificial lighting and air-conditioning in the room is the lowest.A study on the energy and lighting performances for energy-efficient fluorescent lamps associated with electronic ballasts and high frequency photoelectric dimming controls installed in a school building was done by Danny H W and K L Cheung [18]. Electricity expenditures and indoor illuminance levels for a workshop and a classroom employing high frequency dimming controls were analyzed. Simple prediction methods were used to illustrate the lighting savings. Doulos L and Tsangrassoulis A [19] compared the performance of eighteen samples of electronic dimming ballast from five manufacturers to quantify their impact on energy savings in daylight responsive dimming systems for two control algorithms: closed loop and integral reset. The author concluded that the control algorithm dominates the performance of the daylight responsive dimming system. The maximum annual difference in the energy saving values between the tested dimming ballast was estimated equal to 5.9% for closed loop algorithm as against 5.7% for the case of integral reset algorithm.

A digitally dimming control lighting system for the fluorescent lamps for boosting the transmission length and speed with use of a new transmission interface is done by Chun An cheng and Hung Liang cheng [23]. A compact USB based lighting system for two lighting areas are developed and measure using function of remote dimming control in order to improve the transmission speed and to reduce circuit components .The existing control techniques for light control system are fuzzy based [8]. The fuzzy logic controller cannot automatically acquire the rules used to make the decisions. Artificial neural networks are good at recognizing patterns and have ability to train the parameters of a control system, but they are not good at explaining how they reach their decisions. These limitations can be overcome by combining these two techniques as the intelligent hybrid systems neuro fuzzy system. The ANFIS is a combination of a fuzzy logic controller and a neural network is combined, which enables the controller self tuning and adaptive.

C. Wireless Radio Frequency(RF) lighting control

In a wired lighting system, all lights, sensors, and switches are hardwired to a central controller or to a gateway that facilitates communication between the lighting network and lighting control software. RF wireless communication is a significant emerging lighting control technology in both residential and commercial building applications [14]. In a wireless system, control devices communicate through the air using radio-frequency RF waves without the need for control wiring. The lighting control system recognizes each device by a digital address, eliminating the need for physical wiring. So when the controller receives a message from an occupancy senor that has been triggered , it knows where within the network the sensor is located, and which lights should be adjusted in response to the sensor event. A cost effective Zigbee based monitoring and protection system for building electrical safety was done by Li Chien Huanga and Hon Chan Changa [20]. The system was constructed with the protection mechanism in order to enhance the functions of traditional distribution systems. The network structure of the Zigbee in this work is a star topology where the three major components in the system are the wireless communication platform, the smart node and the base node.

Dong Sung Kim and Joseph Jeon proposed a scheduling method of wireless control networks for factory automation using IEEE 802.15.4 networks in the paper [21]. In this study, the wireless control network considered is a star topology which consists of a controller (coordinator node), sensors, and actuators. Hence, the coordinator node is responsible for maintaining dynamic information for scheduling and network performance. For the simulation, the network is configured with 15 nodes for real-time periodic data transmission, using the NS-2 simulator. Maoheng Sun and Qian Liu [15] emphasizes on the implementation of Zigbee protocol and data communication flow for remote light control system. The development of remote lighting control system is based on Z stack 1.4.0. The implementation is PC based and the controlling is manually done by pressing on, off, dimming command.

Ralf Burda and Christian Wietfeld [11] has introduced IEEE 802.15.4 network standard to allow for energy efficient communication of control and sensor data. The multiple parameters which is considered are lighting, blinds, air conditioners and sound systems for the control. How to use Zigbee service environment for the ambient control has been discussed by the authors. The feasibility of assigning IEEE 802.15.4 or Zigbee networks as a wireless backbone in the service deployment layer has been studied and was validated by simulation and experiment. The result has been validated with small set of sample nodes.Zhang Yang Qi and Sun Lei [12] used infrared sensor module, decorative lighting control module and wireless communication module for the design and implementation of intelligent art lighting systems. Intelligent lighting system control algorithm is designed on the basis of the genetic algorithm. Zigbee protocol has been used for wireless sensor networks. Future work [12] was foreseen in the areas of i)designing a variety of sensors in a lighting node, thereby it will be more comprehensive perception of the surrounding environment and ii) designing a variety of environmental modeling based on the number of visitors and the frequency of the sensor to trigger, consequently the lighting can easily replace lighting control model according to the environment.

In the survey done by Jennifer Yick, Biswanath Mukherjee and Dipak Ghosal [24] on wireless sensor network (WSN), the authors identified that the open research issues in the WSN are as follows: the design of a wireless sensor network platform must deal with challenges in energy efficiency, cost, and application requirements. The authors specify that it requires optimization of both the hardware and software to make a wireless sensor network efficient. They concluded that the development of a reliable and energy-efficient protocol stack is important for supporting wireless sensor network applications. Dae Man Han and Jae Hyun Lim suggest a Smart Home Energy Management System based on an IEEE802.15.4 and Zigbee in the paper [26]. The authors developed routing protocol Disjoint Multi Path based routing to improve the performance of the Zigbee sensor networks. Implementation has done in a real time environment.

Y J wen et al [14]presents an energy efficient lighting control system for open-plan offices with a wireless–networked sensing and actuation system and a control method incorporating multiple management strategies to provide occupant specific lighting. Workstation based wireless photo sensors are employed to measure task illuminance, and individual addressability of wireless enabled dimmable luminaires to fulfill various lighting requirements. This research is an implementation of multiple modern lighting control strategies, including daylight harvesting, light level tuning and occupancy control, in open plan offices even with less than ideal configurations. The implementation of the lighting control system has demonstrated a more than 60% potential for energy savings. The recent researches have integrated sensors and actuators with the wireless technology, where the sensors sense the information and the actuators perform the actions based on the collected data from the sensors [28]. The purpose of the wireless ballast actuators is to dim the lights based on the decision made by the controller. Compared to the other wireless technologies Zigbee offers certain advantages like low cost, low power consumption etc [10]. And zigbee is a low data rate wireless mesh technology.

D.FPGA implementation of controllers

It is better to implement control algorithm or controllers on a specific hardware or software architecture to get the best performances in terms of execution time or best ratio performance versus cost. Since the execution of the adaptive control techniques requires many computations, the implementation of such algorithms depends on the PC systems. In recent years the fixed point digital signal processor and the field programmable gate array (FPGA) provide a good solution in this issue [29]. An FPGA has been defined as a matrix of configurable logic blocks, linked to each other by an interconnection network, which is entirely reprogrammable. The advantages of the FPGA include their programmable hardwired feature, fast time to market, embedded processor, low power consumption and higher density for the implementation of the digital system [30]. The FPGA is a reconfigurable device used to place some or all of the system onto the hardware. A field programmable gate array is proposed by Ammar A. Aldair and Weiji Wang [8] to build an adaptive neuro fuzzy inference system for controlling a full vehicle nonlinear active suspension system. For implementing the optimal fraction order PID controller VHDL codes are developed from the control parameters obtained from the matlab program by suing which design and simulation of controller has done.

The research done by Ahmed Sameh and Mohamed Samir [22] depends on the idea of implementing the neuro fuzzy controller, using FPGA tools in hardware. The method that the authors taken is to first perform the offline learning in software and then introduce its finale output structure and parameterized values directly to the FPGA for the hardware implementation. Fuzzy self organizing map (FSOM) and Adaptive Neuro Fuzzy Inference System (ANFIS) neuro fuzzy controllers are built by integrated modules from the VHDL library. The result that they observed from the research is hardware controllers are faster and more accurate.

Shabiul Islam and Nowshad Amin [25] describe the FPGA realization of a Fuzzy Temperature Controller (FTC) using VHDL intended for industrial application. Four modules fuzzification, inference, implication and defuzzification for FTC modeling is done in C++ and then it is converted to behavioral level using VHDL.

III. RESEARCH GAPS

The research gaps identified from literature survey are as follows:

- Design of adaptive controller for building light control integrated with image sensor is not explored so far.
- Integration of wireless technology in building lighting control is still in the preliminary stage and more research is called for.
- FPGA based building lighting control systems integrated with wireless sensors is also an open area to be explored.

IV. OBJECTIVES

1. To develop wireless networking system for lighting control.
2. To synthesize image processing algorithm for lighting control.
3. To develop and implement adaptive control algorithm for daylight-artificial light integrated scheme (optimizing glare and uniformity).
4. To integrate and implement the developed control modules.

V.METHODOLOGY

As shown in figure 1 the proposed system consists of the following blocks: image sensor, wireless terminals, adaptive controller, dimming ballast and the fluorescent lamp. In this proposed research work a digital camera will be used as the image sensor instead of the conventional sensors like photosensors and occupancy sensors. The sensed image will be transmitted wirelessly to the FPGA board. An adaptive controller will be implemented on an FPGA to set the desired illuminance for the daylight-artificial light integrated scheme.

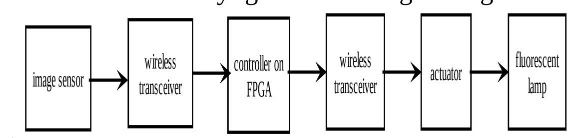

Fig. 1. Block diagram of the proposed system

The block diagram in Figure 2 specifies the basic idea of the control system, where A is the adaptive lighting controller, B is the wireless dimmable luminaire network, C is the illuminated space and D represents wireless networked sensors used to measure illuminance at each workstation. The adaptive controller will perform the following functions: a) Artificial lighting system must be fully on, off or in between (dim) to satisfy the quantity criteria of lighting, according to the task and type of the interior. b) Position of the window blinds must be closed, opened or partially closed to reduce glare & solar gains to provide better uniformity of lighting & comfort in the daylight-artificial light integrated scheme.

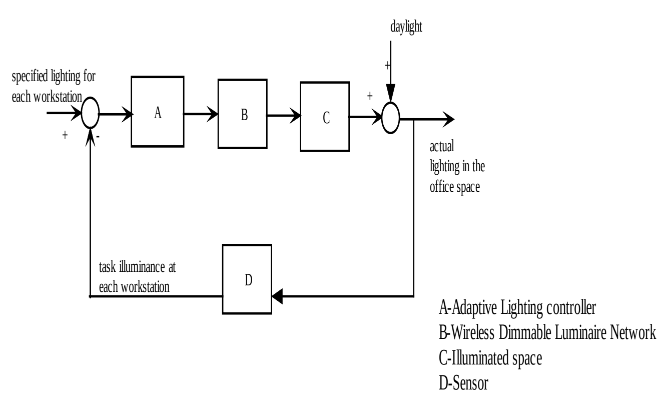

Fig. 2. Basic block diagram of the lighting control system

Figure 3 shows the proposed architecture for the Zigbee service environment based on a star topology. The control loop composed of a controller, an image sensor and the actuators.

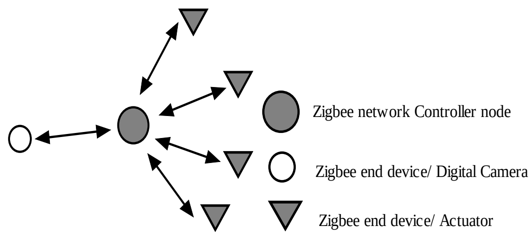

Fig. 3 Zigbee star networking topology for single room

VI. CONCLUSION

With the wide application of the lighting control system which integrates microelectronics technology, optoelectronics technology and computer and information technology, the research on it has gradually become an important issue. Energy efficiency strategies based on daylight-artificial light integrated schemes have proved to be efficient by many researchers world-wide. But much larger energy savings with the benefit of visual comfort, thermal comfort and flexibility can be achieved when systems integration strategies are competently designed [28]. According to the energy code and green building rating systems ASHRAE (American Society of Heating, Refrigerating, and Air-conditioning Engineers) 90.1-2010-Part 2 and LEED (Leadership in Energy and Environmental Design) certifications, lighting controls are critical components for saving energy in buildings. Wireless communication is a significant emerging lighting control technology. The methodology defined here is the research proposal. The future work includes the modeling and simulation of control system and the hardware implementation of it.

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