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Innovation in Buildings - A Move towards Intelligence in Building Physics

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***Abstract*—The heating, cooling and ventilation in a building are directly affected by presence of the occupants and their behavior in buildings. Further, variation in consumption of energy due to electrical appliances like fan, air-conditioner, lights, building controls etc. increases with inappropriate utilization of the resources. Unawareness about the use of energy utilization within buildings can result into the increment of energy consumption in the buildings by one-third. Reduction in energy wastage can be easily achieved by some smart system. Present era is all about intelligent or smart built closed environments, which is being planned and implemented enthusiastically in modern buildings and structures. To be very specific, what the word "Intelligent" mean is critically essential. Present communication states various common definitions explaining intelligent buildings (IB). These definitions are based on their details given in many articles in terms of meeting comfort requirements from an occupant point of view along with reducing energy consumption and fulfilling basic day-to-day necessities.**

Keywords—Intelligent Buildings, Energy consumption, thermal comfort, Automated Buildings

I. INTRODUCTION

Buildings are responsible for unexpectedly 40% of the total consumption of energy globally [1] whereas in United States, 41% from the total energy has been consumed by buildings [2]. In India, Buildings are surprisingly responsible for the 35% of total consumption of energy and use of building energy is growing at rate of 8% annually [3]. In the year 2004, energy consumption in European buildings was found 37% of the total energy, which is higher than that of Transports and Industry which is 32% and 28% respectively. In the United Kingdom, the quantity of the consumption of energy in buildings is 39% which is slightly more than that of the Europeans [4].

As per the report of Energy Information Administration (EIA) International Energy Outlook (IEO) 2017 [5] report, it has been found that the growth rate in the consumption of energy in India will be fastest among all the regions of the world by 2040. According to IEO 2017 the consumption of energy, as estimated for both the commercial and residential buildings, in India will be incremented by an average of 2.7% per year between 2015 and 2040, which is more than double the worldwide normal increment.

The majority of this development is the consequence of increased utilization of natural gas and electricity and the expanded use of machines and energy utilizing devices. In spite of the quick development in consumption of energy in buildings, the reference case of IEO 2017 demonstrates that, among the referred areas, India's per capita use of building energy through 2040 is the second most reduced after Africa. Extensive appealing technologies exist which tremendously reduce the use of energy in buildings but at higher returns and low expenses when compared to other segments. These diminishments serve as a key to accomplishment for the International Energy Agency's (IEA) in view of reducing carbon footprint of the planet by 77% till 2050 as called for by the "Intergovernmental Panel on Climate Change (IPCC)".

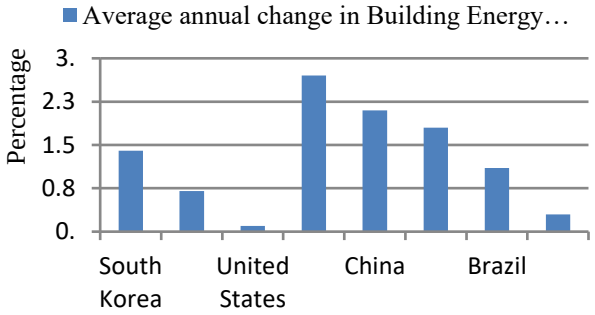

Fig.1. Average annual change in Building Energy Consumption [5]
a figure caption

A research work by World Business Council for Sustainable Development (WBCSD) in 2009 worked to reduce the use of energy in the buildings and reported that it can be reduced drastically to save huge amount of energy equivalent to that being used by whole transport sector. Utilizing higher amount of electricity from renewable sources, (for example, sunlight based and wind) will address the issues pertaining to the environmental change, as well. Additionally we can say that for the decades, it is not possible to use the non carbon sources completely. So better option is to use the sources which are having low carbon content which results in the reduction of usage of energy and ultimately reducing the total cost. Intelligent structures which encourage smart control over the buildings are turning into fashion of the new generation structures. Many studies have been conducted on the intelligent/smart buildings and it has been observed that in past few years, the interest of people has been increased towards the intelligent/smart buildings.

Till date there are many studies conducted relative to the investigations on smart structures and their execution in a built volume. Few from those were discussed here. According to Kell [7] intelligent building has been progressively seen as one that gives compelling, responsive and steady condition

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inside which an association can meet its execution goals. The technology, albeit still for the most part thought to be basic, is currently observed as the empowering influence rather than as an end in itself. Intelligent Building Institute (IBI) firstly utilized the term "intelligent buildings" in the eighties and also defines [8] intelligent building as a structure which incorporates different systems to adequately oversee assets in a planned mode to amplify: investment, performance, cost savings and adaptability. Recently a working group of Capacity and Institution Building i.e. W98 [9] delivered a statement on Responsive and Intelligent Buildings by saying that "intelligent building is a responsive and dynamic engineering that furnishes each inhabitant with productive, eco-friendly conditions and cost effective through a persistent connection amongst its four essential components: Processes (control systems, automation), Places (structure, fabric, facilities); Management (performance, maintenance) and People (users, services) and also understanding the interrelation between them.

Buckman et. al. 2014, [10] suggested a more detailed meaning of intelligent buildings and determined that Intelligent Buildings are the structures which incorporate and represent enterprise intelligence in terms of construction and control, in terms of building life-span and comfort for occupants. In accordance to their past examination Buckman et. al. 2013 where they described intelligence as a part of intelligent structures: enterprise, control, intelligence and design & materials [11]. All things considered, Clements-Croome (2013) [6] portrayed smart structures in three fundamental segments:

- A scope of advancing computerized innovations for empowering Smart quality.
- Sentient design of buildings which reacts to physical and social wellbeing.
- Sustainability based upon utilization of resources like vitality, water and waste.

Ghaffarian hoseini et. al. (2015) [12] described intelligent building structures as a point of convergence grasping green, smart and sustainable characteristics. As per their proposed definition, smartness was just a marker of intelligent structures. rIn view of their examination, intelligent structures ought to be planned and created by four key execution pointers: economic & cost efficiency, smartness & technology awareness, environmental responsiveness and personal & social sensitivity. Turner (2016) [13] investigated about the actual meaning of intelligent buildings by undergoing essence of intelligence and drawing more attention to the emergent intelligence than the executive intelligence. Kuo et. al. (2017) [14] investigated intelligent green building related approaches, meeting the objectives of the current environmental change (COP 21). Lilis et. al. (2016) [15] explained that building robotisation has resulted into intelligent building and the future of these buildings. Their vision of intelligent buildings is found to be in line with the emerging technologies like intertwining of the internet of things and people centered design. The main focus of this study is to provide appropriate living conditions to inhabitants as per their need and requirement.

II. INTELLIGENT BUILDINGS

In general, intelligent buildings are the buildings whose control systems are self-reliant with system using sensors relaying data and based on latest technologies for maintaining the visual comfort, indoo thermal comfort and good quality of air. Energy management is a good tool for such a management as it is required for HVAC, lightning and for warming the water. Indoor comfort is affected by many factors i.e. temperature, solar radiation, air velocity, humidity along with activity and clothing. Building Energy and Comfort Management (BECM) is an important tool for this. BECM systems are the type of a control system which is used for either single building or a group of buildings. BECM systems use microprocessors and computers for observing, communication and data storage [16]. The main target of Building Energy and Comfort Management system is to accomplish the inhabitants' desires for comfort along with that reducing the consumption of energy during the building operations.

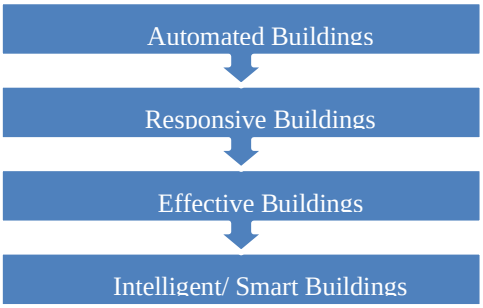

Fig.2. Cycle shows origin of intelligent buildings

Wigginton and Harris [17] explored thirty different definitions for the term intelligence in connection to structures while Wong et. al., [18] talks about the finest available technical and academic definitions of term intelligent building. Amongst all, two definition which are most frequently acknowledged were given by European Intelligent Building Group (EIBG) of United Kingdom (UK) and United States (US) based Intelligent Building Institute (IBI). The EIBG characterizes that smart/intelligent buildings provide sustainable conditions for inhabitants in the building, along with that empowering proficient management of the assets with minimum life-time expenditures of equipment[17] while IBI characterizes Intelligent buildings which provide financially effective condition through improvement in its 4crucialconstituents including system, structures, administrations and interrelationships between all three [17]. Therefore, an IB can be consisted of ten Quality Environment Modules (QEM) [19]. These modules (M1–M10) includes:

MODULE 1	Environmental friendliness
MODULE 2	Space flexibility and utilization
MODULE 3	Cost effectiveness
MODULE 4	Human comfort
MODULE 5	Working efficiency

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MODULE 6	Safety and security measures
MODULE 7	Culture
MODULE 8	High technology image
MODULE 9	Construction process and structure
MODULE 10	Health and sanitation.

III. COST ANALYSIS

After defining the meaning of Intelligent Building, the next foremost essential phase is to estimate the economic feasibility of that. An orderly technique for such an appraisal has been set down. The estimation of value of structure relies totally upon the life cycle expenses and advantages. Distinctive plans will, obviously, infer distinctive advantages and expenses. When we contrast a traditional working Building with an Intelligent Building, based on a similar site, we ought to expect distinctive pay streams, and consumptions. Reducing these normal expenses and advantages gives two figures of net present values. The Intelligent building approach is economically feasible, only in a case if it gives high net present value when compared to ordinary approach. After the meaning of Intelligent Buildings is explained in detail, distinction in advantages and expenses can be reviewed. Beginning development expenses might be higher yet the repetitive expenses might be brought down and Intelligent Buildings potentially last more. Cost information, capital and intermittent, for both regular and smart structures, can be recovered from the information bases of various nations however the strategy is all inclusive.

IV. INNOVATIONS

In this paper, term 'energy intelligent buildings' is used for the buildings furnished with the technologies which permits monitoring of the users or/and facilities which are designed in order to optimize and automate the appliances control, particularly HVAC system, home appliances and the lights with the end goal to reduce the energy consumption. For a thorough review of various intelligent/smart buildings whose main goals are monitoring mobility & physiological parameters, improving comfort, delivering therapy and dealing with medical rehabilitation, one should refer to [20]. There are many energy efficient buildings, designed in order to take following advantages:

- Reducing the demand of energy by including materials, equipment and designs which were more energy-efficient.
- Convert renewable resources into useful form.
- Smart grids technology generates surplus energy that can be utilized in buildings.

A. Green Buildings

Green building is an attempt to make structures and utilizing processes which are resource efficient and eco-friendly throughout the life-cycle of building: beginning from plan, design, development, construction, maintenance, refurbishment and demolition. This needs close participation of the architects, the engineer, design team and the customer at all the stages of the project. The green building practice expansion and supplements the traditional building configuration worries of utility, economy, utility, comfort and durability. While new advances in the technology are always being developed in order to compliment the recent acts in making greener buildings with the basic target to design green structures in order to diminish the effects of the built environment on the health of humans and the environment by proficiently utilizing water, energy and other assets, by ensuring users wellbeing and enhancing worker efficiency, or by decreasing waste, contamination and natural debasement.

B. Door Opening and Closing with Automated Human Sensing System

In this design, the Passive Infrared (PIR) sensor has been used to detect the presence of a person based on the infrared levels emitted. The output of the PIR sensor is used as an analog input to the system, which processes the input and manages signal timing. When the PIR sensor outputs HIGH, the system will open the door via the motor driver circuit. If the PIR outputs LOW for more than six seconds, the door is then closed.

C. Fingerprint Based Door Opening

Fingerprint based door opening is the one of the technique which can be used to open/ close the door. Actually this feature provides additional security to houses. As every individual has different finger prints so it will ease the process of opening and closing the door and adds additional security also. By using this feature, keys are not required to open the doors and also will reduce the problems of peoples who lost their keys generally.

D. Security Systems for smart Homes:

This is a straightforward and compact security alert framework to safeguard the homes/shop and assets. The circuit is worked around a little microcontroller chip. Furthermore, an instant Passive Infrared (PIR) module is incorporated with the alarm for dependable detection of the human movement. The implicit PIR sensor detects the movement of human by detecting changes in temperature. The changes in the temperature of Human body warm will trigger the Infrared sensor, and will send a signal to the control circuit right away. As a result the lamps or sirens connected with the system will get activated and about that.

E. Lighting *Systems* for Smart Homes

At this area client will have the capacity to control the light in Smart Homes by two diverse ways. First one is with the help of smart phones or by the help of Passive Infrared sensor automatically. There were either on/off switches or dimmers to control the lightning systems. Dimmers are the devices which are used to vary the brightness of lights. Dimmers can increase or decrease the brightness as in case of fans. The function of the regulator of fan is same as that of dimmers.

F. Smart Curtain Control System

Curtain control can also be suitable smart system, making the living of occupants comfortable inside the homes. Automated curtain controlling or window opening framework can be controlled through remote switch or even through smart phones. It reduces the human effort and makes building an intelligent structure. Problems like pulling heavier curtains is not easy for every inhabitant in the building so motorized

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curtain can be a solution to this problem. Operating blinds or curtains can be programmed as they can be programmed to open in the morning to let in sunshine and shut down during evenings or as per the requirements.

G. Smart Heating Ventilation and Air-Conditioning Systems

In almost every home, the consumption of energy in the operation of HVAC systems is major part of the total energy consumption which leads it to account for the almost 60% of the electricity bill of the house. In spite of this, most homes squander a huge measure of this energy through inefficient utilization. Effectiveness can be altogether enhanced by just initiating the warmer, fans or ventilating when you were at home and by just warming or cooling to a correct wanted temperature. All things considered this can be accomplished by utilizing intelligent control framework. Intelligent control, in light of the data gathered by the utilization of cell phones and wearable gadgets, increases the collaboration with inhabitants and does the expectation causing control. It may be possible with two different ways:

- First way is to control the system with the help of GPS system of mobile phones or by personally scheduling, for perceiving the information regarding the position of occupants and their intentions of entering the enclosed space. When individual enters the room, at that moment, compressor will be turned on which is generally in off position.
- Other way to control the HVAC system is bracelet based control system. Bracelet is equipped with the accelerator sensor. When the occupants went to sleep, the accelerator reads the human body movements and will increase the air conditioner temperature automatically as the occupants went for sleep. This will ultimately results in the reduction in the utilization of total energy.

H. Smart Bathrooms

- First and foremost common bathroom item is sensor based soap pump. Soap pump are used so commonly in order to wash hands. If we use sensor based soap pump for washing hands, it will lead us to touch free and germs free washing of the hands.
- Second and an important item used in smart homes is sensor based mirror. The work of this mirror is to light up the face of individual when they move towards the mirror and utilizes an light system which simulates the natural light from sun, which enables us to see the complete color variation.

I. Use of Renewable Energy

There were many cases in which we avail renewable energy sources in our homes. First one is the case of cooling system in houses. Photovoltaics cells can be used for the purpose of cooling by its regular absorption/adsorption or compressor based system, although the most widely recognized implementation is with compressor based. For a small private or office building cooling (under 5 MWh/a) PV-fueled cooling has been the most as often as possible executed sun based cooling innovation. Second one is the use of solar energy for heating the water. Sunlight based water warmers utilize the sun to warm the water, which would then be pumped through the radiators. This framework is significantly less expensive than utilizing gas or electric power to warm the water, and is less difficult to introduce the panels. In case you're not willing to totally focus on fueling your whole home with sustainable power source, sunlight based water warming can be a decent option. A geothermal based heat pump utilizes surrounding Earth temperature to enhance seasonal energy efficiency ratio for warmth and cooling. A deep well recycles water to separate surrounding Earth temperature (normally at 2 gallons of water for every ton every minute). These "open circle" frameworks were the most widely recognized in early frameworks; however water quality could make harm the curls in the warmth pump and abbreviate the life of the hardware. Another technique is a shut circle framework, in which a circle of tubing is keep running down a well or wells, or in trenches in the yard, to cool a halfway liquid. At the point when wells are utilized, they are inlayed with Bentonite or another grout material to guarantee great warm conductivity to the earth.

J. Exergy Analysis in Buildings

Energy Analysis give an extremely valuable information and acts as an important instrument to enhance the energy used by a specific system and its components. Exergy clarifies univocally the concept of quality of energy. Exergy and anergy calculations provides a physical significance to the idea of entropy, from which anergy is derived. Decreasing the exergy losses either in a framework or a procedure and expanding its exergy proficiency intends to utilize vitality in a more judicious manner. High exergy general efficiencies mean using all the accessible exergy in a substance and utilizing vitality in the most level headed way.

K. Awareness:

Engineers such as mechanical/electrical/civil engineers explore the life cycle of the buildings and try to make the building technological systems more advanced. Actually if we speak out about mechanical engineer, there major work is to implement an efficient Heating, Ventilation and air conditioning system whereas role of civil engineer is to design the efficient buildings. But there must be proper awareness among both the engineers in order to design an efficient build environment. As there were much software's which a mechanical engineer knows but civil engineer can't. So in order to make energy efficient building there must be proper awareness among the engineers of other departments also.

V. CONCLUSION

Smart Buildings are the structures which incorporate and represent enterprise intelligence in terms materials, construction and control as a whole building framework. Recent studies have shown that controlling in almost all buildings is mostly done physically from switching fans to lights and even to control HVAC systems. However, Automations in Buildings are usually limited to the control of lightning systems with simple detection of motion and to fixing timeout or could be based on indoor climate CO2 level and temperature. However, the activities and behavior of occupants impact the consumption of energy in buildings (i.e. retail sectors, offices and residential) at large. A huge quantity of energy used in the buildings can be reduced just by installing appliances as per the actual need of consumers.

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In BECM systems, use of wireless networks had a very important role in providing nonstop and flawless monitoring of data in the building, which laid the basis of energy efficient buildings. The sensor based network can be used as a mechanism for the identification of the occupants by creating diverse profiles of the occupants residing in the buildings. Bearing energy preservation cost is not a big deal when enormous expenditure is already there in various applications like medical-monitoring and security systems. All above stated factors if considered, remote sensor systems can be the encouraging and adaptable advancements for making minimal effort, cost and simple to deploy sensor in energy intelligent structures.

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