International Journal of Electrical and Computer Engineering (IJECE)
Vol. 9, No. 2, April 2019, pp. 783~788
ISSN: 2088-8708, DOI: 10.11591/ijece.v9i2.pp783-788

Institutional smart buildings energy audit

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Article Info

Article history:

Received Apr 1, 2018
Revised Oct 23, 2018
Accepted Oct 30, 2018

Keywords:

Fuzzy control
Neural network
BMS
Smart buildings

ABSTRACT

Smart buildings and Fuzzy based control systems used in Buildings Management System (BMS), Building Energy Management Systems (BEMS) and Building Automation Systems (BAS) are a point of interests among researcher and stake holders of buildings' developing sector due to its ability to save energy and reduce greenhouse gas emissions. Therefore this paper will review, investigates define and evaluates the use of fuzzy logic controllers in smart buildings under subtropical Australia's subtropical regions. In addition the paper also will define the latest development, design and proposed controlling strategies used in institutional buildings. Furthermore this paper will highlight and discuss the conceptual basis of these technologies including Fuzzy, Neural and Hybrid add-on technologies, its capabilities and its limitation.

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1. INTRODUCTION

The commercial buildings sector in Australian use a significant quantity of energy which normally leads to negative influence on the environment including significant greenhouse gas emissions and production of non-environmental materials. The building sector today consumes about 40% of the world's total fossil fuel energy [1]. Additionally, the Australian commercial buildings consume about 61% of total energy use by the buildings sector [2]. Moreover, Australian commercial buildings' greenhouse gas emissions have grown by 87% between the years 1990 and 2010 [3]. The building sector is also responsible for nearly 27% of the country's total greenhouse gas emissions and that includes commercial buildings that accounted for 10% of the country's total greenhouse gas emissions.

Building Automation system or management systems (BAS, BMS) include heating-ventilation-air-conditioning (HVACs') system, lightings' systems, fire-fightingand other safety systems, and access control. BMS is cabable to decrease energy-consumption and improve thermal-comfort throughout industrial and institutional buildings [4]. In addition the system is cabable to control, supervise and manage different building's interfacesalso in order to provide users and occupants with strong security, improved-productivity, human comfort, and accurate energy consumption management. However, most of the HVAC and lighting systems are controlled using conventional controller whose function is based on process mathematical model (i.e. ON/OFF control). These kinds of controllers are not appropriate for systems with operating-environment nonlinear as those in HVACs and lightings' systems.

Conventional control technique e.g. ON/OFF controller and classical Proportional-Integral-Derivative (PID) controllers are the most common and popular controllers because of its low cost. Nonetheless, in the long term, the ON/OFF controllers are expensive as their operation is based on low energy efficiency standards [5]. Regardless of the past theoretical research, it is fundamentally impossible to employ existing mathematical models in designing HVAC control systems due to several constraints. Firstly, the calculation of thermal comfort involves complicated processing that makes it impractical to install it in real-events applications. Secondly, mankind's thermal comfort sensation is a rather imprecise due to the way of its assessment variation based on users' preferences. Thirdly, human warm-bodied thermal comfort evaluation relies on various changes which are hard to assess accurately at low cost. The mathematical consideration of mankind bodies thermal comfort is, in fact, a non-linear outcome of the interface between environmental-dependent variables namely mean air temperature, air speed, the presence of water vapour in the air (relative humidity), the mean radiant temperature and other personal-dependant variables such as activity level and clothing insulation [6]. To evaluate indoor thermal comfort standards, the environmental variables have to be evaluated at a base location close to the residents and their activity level, as well as their clothing nature and its insulation which, in most installations, are not possible.

Notwithstanding the progression made in Building Management System controll, its policy, design, environment, operation, engineering and programming, Heating ventilation and airconditining HVAC and Lighting control systems are quiet not effective adequately cause of the suage of regular and conventional controllers which guides to a more energy usage. Consequently, extra investigation is important to develop controller's operationally and functionality operating various inputs, outputs and feedback system. Fuzzy-logic-based controllers' inputs, outputs and feedback are frequently based on real life events includeing Day light (natural light) illuminance, ventilation, occupants density, the consumption of passive heating and cooling systems and so on.

In Queensland central and northern regions, request for HVAC is growing –which causes to extra electricity usage. Intelligent and Smart buildings control systems own the cabaability of energy savings by put in a set of rules which are came from real-life events example climate data, irradiance, occupancy and etc. Further study is thus necessary for designing and developing an advanced fuzzy logic controllers for smart buildings in subtropical climate which has been addressed in this study.

2. BUILDING'S ENERGY AUDITING

A commercial building's operational cost reduction, reduction of greenhouse gas emissions related to the usage of fossil fuel and conventional energy resources, energy conservation strategies and a building's energy efficiency are a focal point of importance between researchers, building designers and engineers. In additions, a building's energy efficiency as well as expansion in the usage of renewable energy resources have the potential to avoid the necessity of building extra conventional power stations a combined with little costs and also with minimum negative impacts on the environment. Moreover, a building's energy efficiency and the employment of energy conservation strategies provide the following advantages:

a. Strong economy: According to [7], investments related to buildings' energy conservation offers a better pay back period and a better worth factor than energy supplies projects.
b. Increase the potential of using renewable energy resources and it will allow a wide spread of renewable energy instalments.
c. Provide better environmental conditions and consequently it will improve health conditions.

According to [8], a building's Energy auditing is defined as a cyclic inspection of an energy system (full or partial) to guarantee the most suitable sources of energy are utilized efficiently. Energy management systems using known and systematic energy audit program fits both institutional buildings and also other commercial buildings.

Various investigations on buildings' energy and thermal evaluation and audit have been circulated throughout the literature review. Institutional buildings' energy consumption is high and its estimation is difficult because of radiation in local weather conditions, the building type, system specifications and kind of Heating, Ventilation and Air-conditioning (HVAC) kit employed [9] have developed an institutional building energy consumption life cycle analysis in order to decrease the negative environmental impact and therefore create environment operation standard based on energy usage.

Have examined electrical energy usage pattern of office building HVAC system using energy audit as well as workplace surveys in order to attain a itemisation of the energy usage. Retrogression practises have been applied to connect the monthly usage of electricity in accordance to the design, weather conditions changes and energy usage pattern [4]-[6]. Has observed and examined an institutional building yearly energy consumption in order to design an energy-efficient building and thus achieving substantial energy savings including energy source and cost [10]

A fractional evaluation and energy audit were executed on a newly structured building and various factors and energy practises were examined in order to assess the execution of buildings energy management systems (BMS) [11], [12] have summarized the energy and thermal performance of residential and commercial small scale buildings and realised that the measured values of energy usage were same to predict probable value which was utilise throughout the building pre and post design eras.

To classify the conservation opportunities and know details on the existing technologies, energy Audit has been carried out in this study. This study has assessed energy efficiency in Australian commercial buildings which is considered as main measure of the local and federal government's strategies to bring sustainability.

Have mentioned that, in order to improve institutional buildings energy efficiency; energy audit should be the first step [13]. Energy auditing can be carried out differently to suit different sectors requirements. American Society of Heating, Refrigeration and Air conditioning (ASHRAE), task 56, article 34 classified buildings' energy audits into four sets: Walk-Through Audit, Utility Cost Analysis, Standard Energy Audit and Detailed Energy Audit. In order to carry out a building's energy audit, normally several tasks should be performed based on the building's type and the selected type of the audit. Several tasks might be repeated, minimized in range, or removed based on the results of other tasks. Hence, the completing of an energy audit sometimes is iterative and not a linear procedure.

Generally, energy analysis tools for the assessment of building systems normally categorized into forward and inverse building audit. The inverse building patterns are easier to deal with than buddings forward audit pattern. In the forward audit pattern method, the energy projection depends on a physical building layout, e.g. building site, materials and construction details, and mechanical and electrical system and building function and nature. Most of the present energy simulation engines and software including DOE-2, TRNSYS and EnergyPlus/DesignBuilder the forward auditing and modelling handle.

The majority of the inverse auditing models, for example the change-point models [14] or the variable-base degree-day models tools or connectionist approach [15], depends on retrogression examination in order to classify a building's limitations .

Energy analysis tools are used to capture the dynamic behaviour of building energy systems. Thus, energy analysis tools can use either steady-state or dynamic modelling approaches. In general, the steady-state models are utilized to analyze annual building energy performance. However, to assess the transient effects of building energy systems, for instance those encountered for thermal energy storage systems and optimal start controls, dynamic models may be required. Commonly used energy analysis tool are categorized as Ratio Based Methods, Inverse Methods and Forward Methods [8]. Ratio-based method is a pre-audit analysis approach and is not within the scope of this study.

3. BUILDING MANAGEMENT SYSTEM

A Building Management System (BMS) is defined as a computer-based control system that derives, manages, supervises and controls buildings' mechanical and electrical outlets as shown in Figure 1. Accurate design, installation and operation of BMS lead buildings energy performance to be improved and thus a substantial energy savings could be achieved. Moreover BMS can monitor and control buildings' electro-mechanical gears such as HVAC system, lighting system, power utilities, fire-fighting system, and facility security systems. In addition BMS also is able to plan indoor thermal and visual comfort throughout commercial buildings and institutional buildings also BMSs are capable of reducing energy usage. They also have the capability of supervising and control different building's interface within the building also to provide its users with enhanced security, enhanced productivity, human comfort, and efficient energy management.

In Australia, an accurate BMS is able to provide the essential management needed by building operators and managers to guarantee fulfilment and compliances with Green Lease requirements, for example National Australian Built Environment Rating System (NABERS), Energy Management Plan (EMP) and, most importantly, to reports for the Building Management Committee (BMC).

Active BMS deployment permits ideal building operation and energy-efficient performance throughout increasing the operational life cycle of installed mechanical and electrical instruments and building interfaces by means of reducing loads and as well reducing operating hours – leading to minimum maintenance and operational costs of buildings. A BMS is able to illustrate any elevation in energy usage as a result of systems breakdown or changes in operating settings, e.g., heating valve operation when the building requires cooling or the lights have been left on after working hours or during holidays.

For a building without a BMS, the influence of unusual occasions can be hidden by seasonal differences, changes in occupancy density, and in cases of systems development. An accurately constructed BMS, alongside a sufficient number of monitoring and supervised outlets, is the quick and easy method of delivering reports to building managers and operators, so they can be quickly alerted to any defaults and malfunctions. Another positive facet of BMS is that they are considered a primary means of recognizing energy-concentration enhancement prospects.

In the last decade huge efforts have been made between researchers in order to promote and enhance BMS in newly constructed and refurbished buildings [16].

However, BMSs whose functions are based on ON/OFF, temperature control and, in some cases, humidity control is not the ultimate solution to save energy. The reason behind this is that conventional controllers do not take into account real-time events such as the number of occupants, indoor air quality (IAQ), natural light illuminations, and unlike fuzzy-logic-based controllers. In the last decade there there has been a great deal of interest in researching fuzzy-logic-based controllers as they have the cababiliy saving energy while keeping indoor-comfort level.

4. MODELING AND SIMULATION SOFTWARE FOR BUILDINGS ENERGY SYSTEM

Simulation methods are recently existed in order to assess building energy consumption and also to arrange retrofit plans. The simulation can be used to develop interaction between climate conditions, occupants, HVAC and electrical systems in a building. Simulations are usually employed in a situation by situation basis. An optimal combination of the characteristics of an air conditioning system and the control strategy can be tested and implemented in TRNSYS combined with MATLAB.
Computer-based simulation engines have become a standard mechanism for examining new techniques, the practical examination of control systems – this is considered as a natural subsequent level for this study. Institutional buildings are sophisticated and this sophistication requires the testing within the building's modelling engines to select the best model. Some of the modelling software available for building energy systems modelling are briefly described below.

4.1. Base energy load

EnergyPlus is considered as an energy simulation engine intended for buildings energy behaviour modelling with all their related HVAC, lighting, and other energy linked user. On the other hand DesignBuilder (DB) utilise EnergyPlus (EP) algorithm as the simulation method. EnergyPlus is expressed as "an energy performance analyser and thermal load simulation engine" (U.S. Department of Energy, 2016). Its function relies on a user's explanation of a building from the viewpoint of the building's physical character, linked to existing mechanical systems, etc. EnergyPlus can evaluate the thermal loads required to maintain thermal occupants' preferences set-points. Some key features of this software, as selected from the thorough report in are:

a. Integrated, immediate answer where the building response and the primary and secondary systems are strongly linked (iteration carried out when essential).
b. Hourly, user-defined time steps for the collaboration between a building's various thermal zones and the surrounding environment; adjustable time stages for communications between the thermal zones and the HVAC systems.
c. Heat-balance-constructed key method for building thermal loads which allow for immediate computation of solar radiant gain and convection heat influence at both a building's internal and external surfaces through every time step.
d. Loop constructed defined HVAC systems (conventional and radiant) which permits users to model standard systems and marginally improved systems.

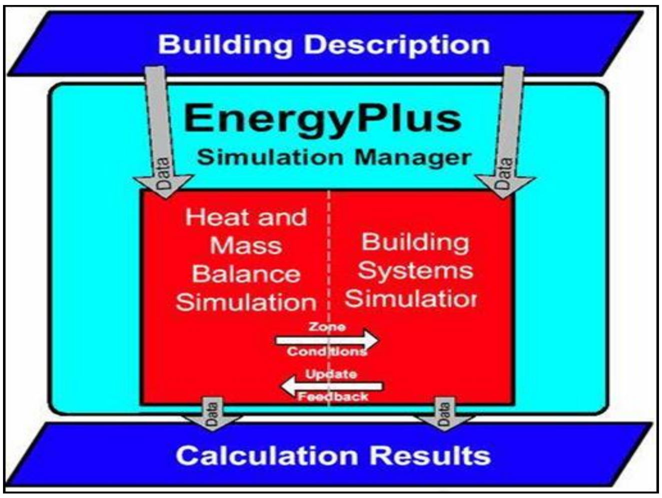

Figure 1. EnergyPlus summary (U.S. Department of Energy, 2016)

The main purpose of Predictor is that it can project the required HVAC system load in order to maintain the indoor air temperature and then simulate the HVAC system behaviour in order to evaluate the effective load. In addition, The EnergyPlus software reutilize the values to compute the zone air temperature balance to evaluate the correct load temperature. EnergyPlus, loads are calculated hourly based and then are passed to the building systems simulation part at the same time.

4.2. Design builder

DesignBuilder is considered as the most complete user interface simulation engine to the EnergyPlus dynamic thermal comfort evaluation and simulation engine. It joins instant building location, geometry, outdoor and indoor environmental systems. DesignBuilder delivers a strong and compliant method in modelling indoor comfort standards in every comprehensive and full feature with an appropriate range of elements including all ASHRAE 90.1 standard. The correlation between EnergyPlus and DesignBuilder is shown is Figure 2. The Figure shows that, the building energy system is described in DesignBuilder platform as an input fed to into EnergyPlus, the simulation process is achieved using EnergyPlus and thus the output of the simulation process is shown in DesignBuilder [18].

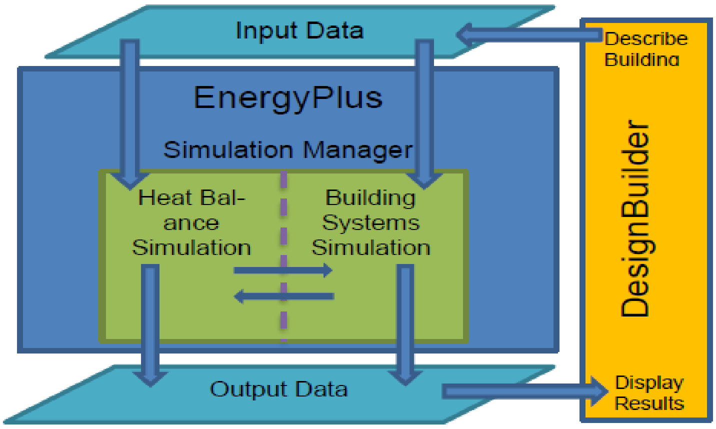

Figure 2. Interaction between energyplus and designbuilder [19]

4.3. TRNSYS

TRNSYS is defined as a transient simulation engine that works using FORTRAN which has been created by the Solar Energy Lab (SEL) of University of Wisconsin, in order to simulate the operation of thermal and electrical energy systems such as solar thermal energy and solar photovoltaic system. The software has been around since 1975 [20]. The software has been widely employed to simulate building energy efficiency and performance. It is also considered to be a software with flexible open-source architecture by enabling the addition of mathematical models, the available add-on components, and the possibility to line and corporate with different simulation programs such as MATLAB. TRNSYS assembly in its nature modular and maintains significant range of various energy system elements which are known as Types [20].

4.4. DAYSIM

DAYSIM is authenticated software that its performances are based on radiance of daylight analysis. The software is able to model the used total yearly quantity of daylight inside and surrounding buildings. DAYSIM permits users to simulate and model active facades and natural lighting received from regular venetian building openings to position light redirecting components, dimming, glazing and complex combinations of lighting systems. Users can additional identify composite electrical lighting systems and its controllers such as manual light control switches, occupancy sensors and photocell controlled dimming systems [14].

The software Simulation output varies from climate-based daylighting metrics e.g. daylight autonomy and usage of daylight illuminance to yearly glare and the energy consumption of electric lighting systems. DAYSIM also is able to produce occupancy hourly schedules, the load of electric lighting and the status of shading device that might be straight away coupled with other energy simulation engines such as

EnergyPlus, eQuest, MATLAB and TRNSYS [14]. The nature of DAYSIM as a simulation engine is based on its chain of command-line codes which execute various simulation phases [15].

5. CONCLUSION

The Australian central and northern areas, which known as a subtropical climate institutional buildings are increasingly developed rapidly which required extra electricity energy usage. Smart and intelligent buildings' monitoring, supervise and control systems are capable to save energy compared to regularl control means. This saved energy can be granted by using a set of rules (fuzzy) which wholy relys on real life events e.g. climate data, solar irradiance, occupancydensity and a lot more. The present article has detailed the matter, where energy consumption, indoor thermal and visual comfort and control systems are situations of showed the advancement of intelligent control systems in buildings in order to enhance the efficiency of buildings' control systems.

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