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A review on optimization of energy efficiency in buildings: Smart cities

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ABSTRACT

The massive development of developing countries increases the energy consumption continuously.Energy savings and reduction of emission are the main goals of construction industry. The main objectives to improve the productions of energy and reduction of energy consumption and cost. The consumption of energy in buildings results in direct and indirect impacts over the lifespan of the building which leads to global warming, carbon footprint and indoor air pollution etc. The paper mainly focuses on reduction of energy consumption in buildings as well as all the methods have been discussed to reduce energy. The metamodel-based optimization, simulation algorithms, artificial neural network models, supervised data mining - based methods,Deep neural networks,Sampling method,BIM-LCA integration, data driven methods,clustering based methods, have been discussed to save consumption of energy in buildings.

1. Introduction

The modern society has been urbanized rapidly and energy consumption has occupied a major attentionin the world. Buildings account for 30-40% of total energy usage and also it emits 30% of CO_2 worldwide. In last few years, the total electricity consumed by commercial buildings in India is increasing at a rate of 11-12%[10].Concrete in the construction industry has been widely used and it generates about 25 billion tons of concrete worldwide[9].Many people

stay indoors most of the time working, studying or doing other activities in air conditioning which leads to indoor air pollution and electrical energy hence the buildings have major impacton environment as well as human beings and greenhouse gas emissionsaccountsone thirdand consume a lot of energy[3]. In addition, the materials used in building construction can leads to global warming and carbon footprint.Several design features such as the building's shape, wall and roof construction, foundation type, insulationlevels, window type and area, thermal mass and shading affect the energy saving of the building shell[2].The consumption of energy in buildings results in direct and indirect impacts over the lifespan of the building. Thebuilding sectorconsumeshuge energy in the world is and these are responsible for energy consumption , such as heating, ventilation and air conditioning systems, lighting systems etc. equipment failureand inadequateregulations of building energy systems are common,resulting in significant energy waste[9].Real time energy management is another effective method for energy efficient buildings which refer to the idea of automatically controlling different energy sources in effective and optimized manner as to reduce the energy costs, by measuring different energy related parameters in real-time such as energy consumptiongeneration, ambienttemperatures.The major amount of energy used in buildings and construction sector is produced from fossil fuels. The energy performance of a buildings are evaluated by taking many effective design parameters and architectural parameters are significant in reducing the building energy consumption[1].It is important to develop methods which minimizes the use of electricity for lighting through best practice design decisions and to do the effective method is to utilize the natural daylight in indoor areas and to achieve a design approach to the placement and size of windows in office buildings is imperative[7]. Through implementing building codes the successful way to boost the energy efficiency of the buildings.These building codes are used to implement minimum standards for building energy quality such as envelope, HVAC, DHW and lighting. Several experiments and studies have shown that building energy codes can save 5-20% energy for the building stock. We should define building energy codes and standards separately before proceeding.Due to the massive development of developing countries, the energy consumption scale increases continuously. The main goal of construction industry is energy saving and emission reduction. Therefore, to improve the energy productions and reduction of energy consumption and cost are the main objectives[8].

2. ENERGY EFFICIENCY METHODSA

Classification based on thermal behavior: EnergyPlus simulation system or software forecasts the thermal conduct and energy consumption of a house. EnergyPlus developed by the US Department of Energy and it is an entire energy monitoring system for buildings. EnergyPlus calculates the required cooling and heating loads for the maintainence of thermal control set points and regulates the condition in the secondary HVAC system and coil loads and the primary plant equipment's energy consumption. The, capabilities,

characteristics of simulation, EnergyPlusfeatures have inherited from the legacy BLAST and DOE-2programs [1].

B.Classification based on cooling,heating and lighting electricity:A multi objective particle swarm optimization (MOPSO) algorithm code is programmed in MATLAB software aiming to implement the simulation-based optimization problem. For the Energy simulation software, the jEPlus method is designed in the MATLAB setting as device coupling functions and decision values are to be replaced on the command script function. The coupling approach uses jEPlus as an interface to check all EnergyPlus features via MATLAB environment to add power to EnergyPlus building simulation software. Through integrating MATLAB with EnergyPlus by jEPlus , the main drawbacks of other current building optimization methods are removed.The three objective functions are considered which are non-linear and coupled are annual cooling, heating and electricity consumption and it was applied to model which single room considering four of Iran's climatic comprises warm-humid, warm-dry, mild and cold regions[1].

C.Data-driven methods

Table I : Different types of data-driven methodsData-driven methods	**Idea**	**Advantages**	**Disadvantages**	**Stability**
Data-driven statistical method	Data is analysed using statistical methods	Appropriate nonlinear and unpredictable structures with lower data level	High-dimensional, messy or redundant data is difficult to handle	weak
Data-driven hybrid method	Statistical methods access the data and neural networks model the data	Redundant ,High-dimensional data can be handled	The scope of the experiment will have the effect and it should not be substantially promoted to a large extent	strong
Data-driven artificial intelligence method	Artificial intelligence methods such as neural networks for modelling and analysis are used directly.	Redundant ,High-dimensional data can be processed	The performance will be affected if the data is bulky, repetitive or messy.	Medium strong

D.Classification based on building load prediction(heating,cooling an electrical load)

Table II: Classification on heating,cooling and electrical load prediction

Regression -based building energy load prediction	**Artificial neural networks-based methods**	**Deep neural network-based methods**	**Support vector regression -based methods**
To predict energy loads of buildings, many regression algorithms have been applied such as artificial neural network (ANN), support vector regression (SVR), autoregressive integrated moving average (ARIMA), deep neural networks (DNN). Regression -based building energy load prediction four steps namely data transformation, feature selection,model parametersoptimization, model training. In data transformation, the accuracy of the predictive model has to be improved by transforminghistorical activity data to uniform scale. In feature selection, the variables which affect the target energy load are to be extracted and these extracted functionalityis used for model instruction. In optimization of model parameters, to obtain the optimal model structurehyper-parameters of the model	ANN is used for building energy load prediction and it is most regression algorithm. ANN is composed of input layer, hidden layer and output layer and artificial neurons are present in every layer and these are linked in adjacent layersto the artificial neurons. In the model training phase , the weights are to be tuned in each connection. ANN was used for estimation of loads cooling and heating apart from electricity load prediction[9].	For building energy load prediction is proved as an effective regression algorithm when compared to ANN, deep neural networks have more complex architectures. The most common type of DNN is recurrent neural network (RNN). The three types of prediction accuracy of RNN are convectional RNN , Long Short-Term Memory(LSTM), Gated Recurrent Units(GRU) in estimation of building cooling load. GRU is known to do the best in cooling load prediction of an education building[9].	For building energy load predictions is widely utilized. In high dimensional space, hyperplane is found which minimizes the predictions residual of the points outside the margins. Compared to other regression algorithms namely ANN and MLR, SVR showed the best prediction performance. When compared to other three types of ANN algorithms such as traditional Back Propagation Neural Network(BPNN), Radial Basis Function Neural Network(RBFNN) and GRNN. SVR has been widely used for the estimation of buildings cooling and heating load.The hourly estimation of cooling load for office buildings is based on the least square support vector machine (LS-SVM) regression

have to be optimized. The prediction of final building energy load model is obtained by tuning the coefficients of the model[9].			algorithm. Compared to BPNN, LS-SVM has more accuracy[9].

E.Classification based on identification of faults:

Supervised methods for detection and to diagnosis of faults for building energy systems are to detect and to diagnose faults in devices and sensors , and supervised data mining technologies ae used in energy systems of buildings. Unless the faults which are detected are repaired in time , then the efficiency of the energy systems of building can be increased in operation. This is divided into two groups, approaches focused on regression and classification methods[9].

Table III: Methods classified based on faults identification

Regression based methods	**Classification-based methods**
These are usedfor the production of benchmarking FDD models . If the faults are only observed if the real measurements deviate from the benchmarking. To develop benchmark models, ANN has been widely used. To estimate the values of benchmarking of supply -air temperature, mixed air temperature, statistical pressure and air flow, fourbenchmarking models on GRNN are being created. Faults and deterioration of AHUefficiency are identified by using the residuals between the bench marking values and actual values[9].	The multiclass classification algorithm and classification of one-class algorithm are the two kinds of classification to be used for FDD. Four SVM classifiers of two-classhave been developed and the first classifier detect the systems that have faults or no faults . If there are faults ,then the other three classifiers are used to determine the faultsthat occurred. ANN has been used toidentify and diagnose multiple-faults and classify the data into various types of faults, which are FDD methods based ANN. The temperature of supply air, the pressure of supply air and the location coil valve cooling are the variables taken as the model inputs[9].

F.Classification based on indoor environment distribution

Table IV : Methods classified based on indoor environmental distribution

Clustering - based methods	**Load level optimization**	**Supply side optimization**	**Combined approach**	**BIM-LCA integration**
These clustering algorithms helps to identify building operation patterns such as building energy consumption patterns, indoor environment distribution patternsuch as temperature, humidity and light,checking daily electricity usage patterns and building energy system and patterns of activity of the building data . These algorithms classify each pair of points in the data set of statistical similarity[9].	The building architectural parameters, ventilation and control systems are to be optimized and dealt by load level optimization problems.To make building net zero in order to select optimal design presented by a simulation-based optimization model. The optimization includes design parameters such as Outside walls and roof insulation thickness, form of window glazing,refrigeration and heating level, ratio of window to wall and size of solar domestic water heating device. And it also optimizes to improve building envelope when considering both cost and energy efficiency , such as window, materilas which insulation the wall and thickness[10]	The supply side optimization is second level and it is used for optimizing energy supply system such as CHP and CCHP systems, renewable energy systems, HVAC system design. The waste energy from prime mover has been utilized and exhaust energy has been recovered to produce useful outputs and the works as main in CHP and CCHP systems. To maximize the possible life cycle environmental effect of a building's operating process to meet the demand for electricity, heating and cooling. A life cycle optimization model built and to	The optimum solution for envelope retrofit and renewable energy supply technologies such as biomass boilers, heat pumps, photovoltaic, solar thermal panels which minimizes life cycle cost and GHG pollution. The best alternative for reducing the environmental impact of buildings, on the life cycle is mixed -integer linear programming (MILP) which helps to identify[10].	To protect the built environment and to achieve the sustainability standards in the construction projects-LCA has been used. LCA methodology helps in evaluating environmental impacts and estimate the energy performance in the construction sector.. The main scope of LCA is to focus on the operational phase and to make buildings more energy efficient and consuming 90% of all building energy and it also focuses on reducing the environmental impacts of the building, analysis of alternative building materials[11].

		comparesvarious CHP technologies, the GWP and a possible source to ozone precursor potential was developed[10]		

G.Classification based on optimization

Table V:Various types of optimizations

Multi-Objective Particle Swarm Optimization(MOPSO)	**Multi-Objective Building Performance Optimization**	**Metamodel -Based Optimization Approach**
In 1995, Eberhart an Kennedy developed a Particle Swarm Optimization (PSO) which is population based stochastic optimization technique. The PSO method is started by grouping random particles and update the generations by searching for an optimum. The particle's velocity and the location must be modified after finding the best values. The $x_i(t)$ position is determined by applying its velocity $v_i(t)$ to the current location. $x_i(t) = x_i(t-1)+v_i(t)$ The velocity vector is defined as $v_i(t)=w\ v_i(t-1)+C_1r_1[Pbest - x_i(t)]+C_2r_2[Gbest - x_i(t)]$ w is the inertia weight used to balance the influence of previous velocity of the particle on the current one. C_1 is the driver of cognitive learning factor which attracts the particle to its own success, C_2draws the	The performance of the building optimization can be proposed as a multi - objective optimization problem. It is expressed mathematically min $f_m(x)m=1,M$; where , f_m denotes a particular purpose, x= set of variables for the constructon of n building. The trade-off between the aims $f_1(x)$, $f_2(x)$, $F_m(x)$ is provided by the multi-objective problemsolution. A multidimensional space Z has been created when there is a mutual confliction between the objectives and also the typical decision space X has been created.The building optimization performance has been tackled ,through integrating BPS program with automated optimization algorithm,. Many of the algorithms have developed to solve	The model is more complex and it exhibits input-output relationship of less complex models which are studied by approximate models called metamodels. Metamodels have analytical expressions and can perform well and involves a large variety of simulation tests like sensitivity, instability and real case studies optimization study and has gained attention in BPSapplication. ANN-based metamodels ANN contains artificial neurons which function as information processing units and are parallel computational models. These artificial neural networks can be used in approximation, filtering, regulation, time series analysis, signal processing and association or identification of patterns. Aiming to give desired output or objective, ANN has to be trained with proper set of data in that they match the interconnectioncharacteristics.

particle towards the success of its neighbors and it is the social learning factor . C_1 and $C_2$are considered as positive constants and r_1 and r_2 ϵ [0,1] are the random numbers which includes individual sequences that holds minimum of local trapping away and diverge the smaller particlespercentage in a broader quest space exploration. Best and Gbest shows the best solutions of personal and global that show the speed and the location changes in the particle swarm optimization algorithm[1].	multi-objectiveevolutionary optimization problems algorithm such as MOPSO, SPA2 and NSGA-‖. In all these, NSGA-‖efficiently sorting non-dominated solutions and providing a collection of Pareto-optimal solutions that are well distributed on the the pareto front[6].	The learning process of ANN is achieved by simulation the ANN by an environment, simulation changes in ANN free parameters and bymodifying the internal structure of the ANN by responding in a innovative ways to environment[6].

3. CONCLUSION

The massive energy consumption by buildings results in global warming, carbon footprint etc . In order to reduce consumption of energy or to make net-zero energy building , solar energy wind turbines are also to be added as an energy generation and using wind turbines in cold seasons for generation of electricity is an suitable substitute for photovoltaic panel electricity reductions[4]. Considering site boundary, I shape layout is preferred as it will reduce the heat gain from solar radiation and thermal load and flats which are small sized are always favoured in tower buildings due to lower energy usage and fast cooling[3]. While considering shape features in optimization, in sunny heating environments, south facing trapezoids is preferred and north-facing trapezoids shows good benefitsin cooling climates during the effect of solar radiation through windows compared to any other shapes[2]. Thetriple objective optimization using weighted sum methodresultsshowed that the cooling in a year reduced 19.8-33.3% and increased theconsumption of heating and lighting energy by 1.7%-4.8% and 0.5%-2.6% compared to basic model depending climatic region[1].Future development of standardized,automated and domain knowledge-based data mining methods because these are not mature for practical applications[9].

REFERENCE

[1]Delgarm, N., Sajadi, B., Kowsary, F., &Delgram,S.Multi-objectiveoptimization of the building energy performance : A

simulation -based approach by means of particle swarm optimization(PSO). Applied Energy, pp.293 – 303, (2016).

[2]Tuhus-Dubrow, Daniel, and Moncef Krarti. "Genetic-algorithm based approach to optimize building envelope design for residential buildings." Building and environment 45, no. 7 (2010): 1574-1581.

[3]Gan, Vincent JL, H. K. Wong, Kam Tim Tse, Jack CP Cheng, Irene MC Lo, and Chun Man Chan. "Simulation-based evolutionary optimization for energy-efficient layout plan design of high-rise residential buildings." Journal of cleaner production 231 (2019): 1375-1388.

[4]Adeli, M. Mahdavi, S. Farahat, and F. Sarhaddi. "Increasing thermal comfort of a net-zero energy building inhabitant by optimization of energy consumption." International Journal of Environmental Science and Technology (2019): 1-16.

[5]Bre, Facundo, Nadia Roman, and Víctor D. Fachinotti. "An efficient metamodel-based method to carry out multi-objective building performance optimizations." Energy and Buildings 206 (2020): 109576.

[6]Javid, Atiye Soleimani, Fereshteh Aramoun, Masoomeh Bararzadeh, and Akram Avami. "Multi objective planning for sustainable retrofit of educational buildings." Journal of Building Engineering 24 (2019): 100759.

[7]D'Agostino, Delia, Danny Parker, and Paco Melia. "Environmental and economic implications of energy efficiency in new residential buildings: A multi-criteria selection approach." Energy Strategy Reviews 26 (2019): 100412.

[8] Mardani, Abbas, Edmundas Kazimieras Zavadskas, Dalia Streimikiene, Ahmad Jusoh, and Masoumeh Khoshnoudi. "A comprehensive review of data envelopment analysis (DEA) approach in energy efficiency." Renewable and Sustainable Energy Reviews 70 (2017): 1298-1322.

[9] Kishore, Pranav, Pradeep Kini, and Anupam Raj. "Optimization based feasibility analysis for Energy Conservation Building Code compliance of opaque wall assemblies in different climatic zones of India." Procedia Manufacturing 44 (2020): 221-228.

[10] Wang, Ruijun, Ningning Yu, and Yang Li. "Methods for improving the microstructure of recycled concrete aggregate: A review." Construction and Building Materials 242 (2020): 1181