Identifying Statistical Analysis For Building Performance Simulation.

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Abstract: Since designing a net zero-energy buildings (NZEBs) has many complex parameters and is also largely dominated by mandatory codes and standards like ASHRAE (2008, IEA), the analytical energy modelling of NZEBs becomes a challenging problem. [1]. It is also important to involve the active and passive strategies and the primary assessment of life cycle of a building at the early stage of design itself. This stage involves use of modelling, simulation and analytical softwares. It involves not only high costs but also the degree of uncertainty of decision making is also high. [2] Most of the softwares give results relating to Life cycle assessment and whole building performance of a building.

Keywords: Building technology, Zero energy buildings, zero carbon buildings, Energy efficient buildings.

I. INTRODUCTION

Appropriate softwares shall be used to evaluate the energy performance by simulating the various identified parameters of building envelope performance. Permutations and Combinations of the various parameters shall enable to obtain the optimal building envelope for the given conditions. The results shall be analysed accordingly. The parameters of evaluation and boundaries of assessment shall also have to be fixed

II. STATISTICAL ANALYSIS

A. Simualtion Tools

There are many simulation tools available nowadays. It includes, Autodesk products like Design builder, Revit, Open studio, Green building Studio, etc. These softwares perform the following functions.

- These softwares simulate conceptual energy use in the building by carrying out whole building energy analysis. The whole building energy analysis measures the effectiveness of your energy efficiency measures.
- These softwares can also be used to access, visualize, and analyze weather data to understand the response of the conceptualized design towards the site climate.
- These software simulations also depict the efficiency of HVAC systems for varying yearly heating and cooling loads. This also helps in deciding how tradeoffs can be done to maintain the thermal balance.
- The study of sun's path influences the climate analysis for designing the high performance buildings. It influences the passive design strategies and building integrated power generation systems are the most important components of net zero energy buildings.
- The CFD simulation shows the air flow pattern, which helps in incorporating the ventilation strategies that can be incorporated in the building design.
- Quantitative and qualitative analysis of daylighting in different parts of the building and during different times in the day influence the size, position and building materials for the fenestration.

In addition to the above softwares, plug ins like Radiance and DaySim can also be used for the lighting analysis.

Maintaining the Integrity of the Specifications

B. Parameters of Evaluation

Before There are six main parameters in NZEB design. They are as follows:

1. Metrics of evaluation: Since there are various definitions for NZEBs based on energy, environmental and economic balance, hence the evaluation of performance is also done on various balance metrics.
2. User Comfort: The main objective NZEB is to achieve users' comfort by not impacting the environment and also being cost effective. This requires to define static and dynamic models of the comfort parameter evaluation.
3. Building integrated Passive Strategies: Incorporating passive strategies in architectural design to enhance natural daylighting, cross ventilation, night time purging by providing thermal mass and shading devices.
4. Energy Efficiency: To meet the target of net zero energy consumption or 100 % energy efficiency, NZEBs have to inculcate various energy efficient strategies for energy efficient building envelope performance, low air infiltration rates, reduced artificial lighting and plug loads, etc. For this NZEBs have to comply with energy efficiency codes, standards and rating systems.
5. Building Integrated Renewable Energy Systems: Building Integrated RES are an important part of a NZEB that needs to be addressed early on in relation to building from addressing the panels' area, mounting position, row spacing and inclination.
6. Innovative Solutions and Technologies: The aggressive nature of 'net zero' objective requires always implementing innovative and new solutions and technologies.

C. Uncertainity of decision making

Designing of a building involves multidisciplinary aspects and is an exploratory process with the architectural model being the base plan. Decisions taken in early design stage influence 80% of all detailing decisions throughout the rest of the project till its completion. [3]. For small scale projects it is not very difficult to take decisions by an architect but for large scale projects, engineering solutions are required at every stage. Hence there is high uncertainty regarding performance of NZEB design particularly in environmental impact of the buildings.

D. Defining the variable required

On the basis of Design builder and energy Plus software, following variables are identified:

I. Defining The Variables Required for Simulation

A. Construction Details

When we define a base model, we also have to give specification of various construction components. These include the following;

- External walls
- Roofs
- Floors
- Partitions
- Internal / external doors
- Air-tightness
- Thermal mass
- Glazing details- construction, frames, opening area for external and internal glazing, roof glazing, shading systems.

Different carbon reduction approaches	
Strictly zero carbon	No carbon emission , balancing nor offsets are allowed.
Net zero carbon	All carbon emissions within Scope 1 (direct emissions and removals) are eliminated, and emissions within Scope 2 (energy indirect emissions) are balanced through export of low or zero carbon goods, internal or external sequestration, or import substitution of Scope 3 (other indirect emissions) .
Carbon neutral	Any and all emissions for which the building is responsible under Scopes 1 and 2 can be managed through the purchase of offsets from third parties that lie outside the building's boundaries.
Low carbon	Emissions under Scopes 1, 2 and 3 are reduced compared to a baseline. The reduction level is often not clearly specified.

1. Facade types: types of facade layouts, frame definitions, glazing data (opening/no opening, continuous, height, width.

The walls and partitions can be external /internal and can have exposed/semi-exposed surfaces. Specifications of the construction component that has to be provided includes thickness of the component and properties of the material like transmittance values, thermal resistance, etc.When we specify a wall, cladding systems have also to be defined. They are integral part of the construction. There are two types of cladding systems. They are as follows:

The built up metal cladding systems involving rail and bracket or z-spacer systems with insulation within the panels. For example, metal twin skin systems having 0.4 mm to 1.2 mm thick metal skins and an insulation layer between them.

2. The composite panel metal cladding systems with insulation inside the panels.

However, a rain screen is not considered as metal cladding for calculation purposes as they provide only protection from external weather conditions. We can add up to10 layers to the external wall specification. Properties to be defined:

1. The convection properties of the outer and inner surfaces have also to be defined. For this we need the convective and radiative heat transfer coefficients (W/m^{2-} k) for all the surfaces. If any construction component (e.g. wooden joists) are being used to bridge the inner and outer walls, then their transmittance values (U-value) and Thermal Resistance (R-value) with the upper and lower limits have also to be defined.
2. The construction components also include the internal heat sources like heated floors, chilled ceilings, etc. These systems have pipes/tubes embedded in the construction components. If the hydronic tube heating/ cooling systems are being used then their position, size, thermal properties of the tubes have to be defined for this.

B. Defining boundaries according to the Guidelines for GHG emission reporting in HongKong

- Physical boundaries (usually the site boundaries of the building)
- Operational boundaries (to identify and classify the activities to determine the scope)
- Scope 1 – direct emissions and removals
- Scope 2 – energy indirect emissions
- Scope 3 – other indirect emissions
- Reporting period (usually one year)
- Collecting data and information to quantify GHG performance.

For assessment of GHG emissions, it is necessary to understand the types of emissions, assessment boundaries and carbon accounting principles. Softwares are available for carbon calculation. This helps in deciding the strategy for reducing carbon footprint of a building.

C. Optimisation

The performance of NZEB depends on effectiveness of renewable energy system design. The size of RES can be optimised by performing either a single objective optimisation using Genetic Algorithm (GA) or a multi- objectives optimisation using Non-Dominated Sorting Genetic Algorithm (NSGA-II) of interaction between building energy system models and RES models. The single objective optimisation can provide "best" solution for a given single objective whereas multi-objective optimisation provides rich information for designers to make better decisions. [4]

Sensitivity analysis is conducted on optimised renewable energy system (photovoltaic / wind turbine / bio-diesel generator) to investigate the impacts of variations of input variables on the building performance. The study of design inputs (wind velocity, other load, cooling load and solar radiation) show that:

With 20 % variations in the four variables maximum change in combined objective is about 26.2 %.

- Wind velocity is the most influential factor in building performance (total cost and CO_2 emissions).
- Cooling loads and other loads are considered at the design stage itself.

There are many softwares that can be used for optimisation. These softwares use Genetic Algorithm (GA) for optimisation of hybrid energy systems. Most of them perform single objective optimisation only. These softwares take building energy consumption values as fixed parameters and optimise for minimising the net cost of the project. A comparison of single objective optimisation using GA and multi-objective optimisation using (NSGA-II)for optimal designing the renewable energy systems for the buildings and minimising cost and CO_2 emissions shows that computation time for GA is more than 1 hour and for NSGA-II it is more than 10 hours.

- Integration of building energy system models with renewable electricity generation systems and thermal energy storage. To make this system efficient, the optimal scheduling and programming has to be done.
- Single objective optimisation (minimising CO_2 emissions only and grid interaction index only) gives better results than multi-objective optimisation (total cost, CO_2 emissions and grid interaction index).
- Multi objective optimisation generates pareto- optimal solutions in a single run.
- Sensitivity analysis (single way/ two way/ multi- way) of optimised system shows the impact of the operation variables on NZEB performance. [5]

D. Algorithms Used For Calculations

There are three types of calculation methods used by simulation engines;

- Solution algorithms
- CTF algorithms
- Finite difference algorithms; These algorithms are used for Phase change materials (PCMs), HVAC Chilled ceilings and for constructions using thin sheets of metal.

E. Control of Energy Systems For Grid- Connected And Standalone NZEB

To maintain the energy balance and cost saving reliability it is necessary to develop optimal re scheduling and control methods. The energy systems in a grid connected building that require control are:

- High energy efficiency of electricity generation systems during peak load.
- Weather dependent electricity generating systems like PV panels and wind turbines are difficult to be controllesd during alleviating peak load.
- Electricity generating systems like CCHP (combined cooling, heating and power system) can be controlled effectively to improve the efficiency of energy conversion during alleviating peak load and can also be integrated with renewable sources of energy.
- CCHP can be run under various operation modes; Following the Electric Load (FLL), Following the Thermal Load (FTL), Following the Seasonal Strategy (FSS), Hybrid electric- Thermal Load Strategy, Optimal Operational Strategy, Emission Operational Strategy, Primary Energy Saving Strategy, energy island model operational strategy, operational strategy based on the ratio of the cooling generated to actual building cooling load. And a novel operation strategy aiming at minimising an integrated index.
- Energy storage systems for surplus energy.
- Effective response to grid.
- Management of building systems

There are three types of hybrid energy systems that can be installed in a stand-alone building. These are:

- Hybrid energy systems with diesel generator
- Hybrid energy systems without diesel generator
- Hybrid energy systems with hydrogen storage

F. Uncertainty and Sensitivity Analysis for Robust Design and System Reliability

The effects of uncertainties are considered at the design stage itself so as to avoid non-optimal design of energy systems. Introduction of energy storage technologies and grid connection improves the reliability of the system. Constraints on cost and reliability helps achieve a reliable and cost effective design solution for energy efficient systems.

G. Scheduling and system controls:

In NZEB it is very important to have integration of on/off-site electricity generating systems, energy storage system and controlling systems.

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