Journal of Advances in Science and Technology

Vol. VII, Issue No. XIV, August-2014, ISSN 2230-9659

AN ANALYSIS ON VARIOUS TECHNIQUE OF COOLING LOAD ESTIMATION INTENDED FOR BUILDING

AN INTERNATIONALLY INDEXED PEER REVIEWED & REFEREED JOURNAL

www.ignited.in

Journal of Advances in Science and Technology
Vol. VII, Issue No. XIV, August-2014, ISSN 2230-9659

An Analysis on Various Technique of Cooling Load Estimation Intended For Building

Avinash Patil

Research Scholar, Pacific University, Rajasthan

Abstract – The present work is to demonstrate how some very simple problems are made mathematically complex and seemingly tedious due to academic or business compulsions. There are some problems in which mathematical model are developed after making many simplifying assumptions. But, when it comes to solving these models, very sophisticated and complex schemes are applied. For such problems, dual policy does not make sense and in many cases the problem may be tackled in a simpler way to get comparable accuracy. The present paper reports one such example. It deals with the development and authentication of computer software for estimating building cooling load. The software is simpler to use, needs fewer input data and is more versatile compared to any other commercially available, exorbitantly costly and extensively used software. The effects of significant building parameters like orientation, window glass shade type, number of glass panes used, wall insulation, roof type and floor type can be easily investigated. Effects of all these parameters have been investigated for a typical building block to arrive at an intelligent decision. With any other software or method, it cannot be made so conveniently. All the above mentioned advantages are without sacrificing accuracy and reliability.

---------------------------♦-----------------------------

INTRODUCTION

Heating and cooling load calculations are carried out to estimate the required capacity of heating and cooling systems, which can maintain the required conditions in the conditioned space. To estimate the required cooling or heating capacities, one has to have information regarding the design indoor and outdoor conditions, specifications of the building, specifications of the conditioned space (such as the occupancy, activity level, various appliances and equipment used etc.) and any special requirements of the particular application. For comfort applications, the required indoor conditions are fixed by the criterion of thermal comfort, while for industrial or commercial applications the required indoor conditions are fixed by the particular processes being performed or the products being stored. As discussed in an earlier chapter, the design outdoor conditions are chosen based on design dry bulb and coincident wet bulb temperatures for peak summer or winter months for cooling and heating load calculations, respectively.

The purpose of this paper is to establish error bounds on a simplified building-cooling load model by comparing the results from it to those from a comprehensive computer model. Additionally, this study determines the conditions under which the simplified model is reasonably accurate. If the model is applicable, then energy professionals would be able to use the simplified model for determining cooling loads quickly and easily in evaluating preliminary energy conservation measures.

In commercial buildings, the cooling system is often the single largest user of electrical energy. Determining the amount of energy the system uses is, therefore, important for many applications, including energy conservation. The amount of energy used for cooling can be found with a number of methods. These methods include measuring the usage of each component of the system over a period of time, complex computer modeling, and simplified modeling. The first method is the most accurate, but measuring the energy used by each component is expensive and requires measurements over a long period of time. The second method is more uncertain and typically requires professional consultants a couple of weeks to model a typical commercial building. The simplified model method requires the shortest amount of time and is used for preliminary estimation purposes by energy surveyors. Unfortunately, the simple method is likely to be the least accurate method, which is the major reason it is used primarily for preliminary estimation.

Building cooling load components are; direct solar radiation, transmission load, ventilation/infiltration load and internal load. Calculating all these loads individually and adding them up gives the estimate of total cooling load. The load, thus calculated, constitutes total sensible load. Normal practice is that, depending on the building type, certain percent of it is added to take care of latent load. Applying the laws of heat transfer and solar radiation makes load estimations. Step by step calculation procedure has been adequately reported in the literature. It is a scientific and exact approach, but time consuming and lengthy. Overall heat transfer coefficients for all the components of building envelope are computed with the help of thermal properties of the building materials. For the design conditions and the building materials used, cooling load temperature difference, solar heat gain factors and cooling load factors are calculated. Principles of solar energy calculation are applied to determine the direct and indirect solar heating component of the building. The requisite data of building material properties, climate conditions and ventilation standard are also established and reported. First principle is applied to yields the rates of heat transfer through different building components. All these components, when added up, give the total cooling (or heating) load of a building. This lengthy procedure makes the theoretical approach more of academic interest, which quite often, the design engineers do not prefer.

A widely popular method is by using load estimation forms; standard or developed by the designer/company. This approach saves both effort and time. Although it is an approximate method, it gives quite acceptable results for selecting suitable capacity of air conditioning units. The Air Conditioning and Refrigeration Institute (ACRI) load estimation form is very popularly used. There are many similar commercially available forms, which consist of tabulated data as function of design temperature difference. All the probable loads are included in these forms. These consist of direct solar radiation, transmission load through exposed walls (un-insulated and those with different degree of insulation), partition walls, all the possible types of walls, roof, ceilings, floors and outdoor air load. Sometimes, big companies prepare their own load estimate forms. A third method is by applying computer software, standard and commercially available or developed by the designer/company. Due to omnipresence of personal computers, the third method remains the most popular these days.

LITERATURE REVIEW

The energy usage in a building is dependent on construction, weather, and hours of operation as well as the individual systems that work to cool and heat the building. Models of energy usage must adequately reflect the influence of these factors. The following sections review the literature related to modeling building energy usage with complex computer models and simplified techniques.

Some of the models described are classified as inverse models. Inverse models are based on the empirical behavior of a building and how that behavior relates to one or more driving forces. Therefore, inverse models tend to describe in less detail than a forward model. Inverse modeling is divided into two separate categories, steady state and dynamic. The first subset of inverse modeling is steady state. Steady-state models are models that do not account for transient effects. Advantages of steady-state inverse models include ease of automation and ability to be used on many buildings when utility and weather data are available. Disadvantages include insensitivity to dynamic effects or variables other than temperature. The second subset of inverse modeling is dynamic, which includes neural networks. A dynamic model is a model that does account for transient effects. Advantages include the ability to account for dynamic effects of such variables as mass. Disadvantages include complexity and the need for more detailed measurements to tune the models.

Another model classification is hybrid, which is a combination of steady state and dynamic inverse models or of inverse and forward modeling. Hybrid models focus on combining the best features of each of its parent models to improve method accuracy. Most of the models described here can have variations such that they are classified as a hybrid.

Buildings are built to give a sheltered and agreeable internal environment at all variety in external conditions. The degree to which the coveted inner part conditions could be economically administered is one essential measure of the accomplishment of a building design. In spite of the fact that control of inside conditions is normally credited to the dynamic heating and cooling systems, the design of heating, ventilation, and air-conditioning (HVAC) must begin with an examination of the thermal qualities of the envelope. They impact both the equipment limit and the energy needed for its operation.

Cooling load is the rate at which energy must be uprooted from a space to look after the temperature and stickiness at the craved qualities. The cooling load will by and large vary from the heat gain at any moment of time, because radiation from within surface of the walls and inside articles and additionally the solar radiation impending specifically into the space through openings does not heat the air inside the space straightforwardly. The radiant energy is basically assimilated by floors, inside walls, and furniture, which are then cooled essential by convection as they accomplish temperatures higher than that of the room air. Just when the room air accepts the energy by convection does this energy get to be some piece of the cooling load. The storage qualities of the structure and inner part protests focus the thermal slack and consequently the relationship between heat gain and cooling load.

Yao et al. (2002) made a simplified single zone thermal safety system model to be used as an incorporated design device. This model is determined by a yearly climate document and after that approved through examinations with different projects.

Reproduction for over 150 cases identifying with distinctive introductions, building mass sorts and ventilation rates have been performed. This study infers that this simplified thermal safety system model is a bit excessively shortsighted since it speaks to a greater degree a nonexclusive module instead of a representation of the entire building.

HEATING VS COOLING LOAD CALCULATIONS

As the name implies, heating load calculations are carried out to estimate the heat loss from the building in winter so as to arrive at required heating capacities. Normally during winter months the peak heating load occurs before sunrise and the outdoor conditions do not vary significantly throughout the winter season. In addition, internal heat sources such as occupants or appliances are beneficial as they compensate some of the heat losses. As a result, normally, the heat load calculations are carried out assuming steady state conditions (no solar radiation and steady outdoor conditions) and neglecting internal heat sources. This is a simple but conservative approach that leads to slight overestimation of the heating capacity. For more accurate estimation of heating loads, one has to take into the thermal capacity of the walls and internal heat sources, which makes the problem more complicated.

For estimating cooling loads, one has to consider the unsteady state processes, as the peak cooling load occurs during the day time and the outside conditions also vary significantly throughout the day due to solar radiation. In addition, all internal sources add on to the cooling loads and neglecting them would lead to underestimation of the required cooling capacity and the possibility of not being able to maintain the required indoor conditions. Thus cooling load calculations are inherently more complicated as it involves solving unsteady equations with unsteady boundary conditions and internal heat sources.

For any building there exists a balance point at which the solar radiation (Q_{solar}) and internal heat generation rate (Q_{int}) exactly balance the heat losses from the building. Thus from sensible heat balance equation, at balanced condition:

$$(Q_{solar} + Q_{int})_{sensible} = UA(T_{in} - T_{out}) \quad (1)$$

where UA is the product of overall heat transfer coefficient and heat transfer area of the building, T_{in} is the required indoor temperature and T_{out} is the outdoor temperature.

From the above equation, the outside temperature at balanced condition $(T_{out,bal})$ is given by:

$$T_{out,bal} = T_{in} - \frac{(Q_{solar} + Q_{int})_{sensible}}{UA} \quad (2)$$

If the outdoor temperature is greater than the balanced outdoor temperature given by the above equation, i.e., when $T_{out} > T_{out,bal}$, then there is a need for cooling the building. On the other hand, when the outdoor temperature is less than the balanced outdoor temperature, i.e., when $T_{out} < T_{out,bal}$, then there is a need for heating the building. When the outdoor temperature exactly equals the balanced outdoor temperature, i.e., when $T_{out} = T_{out,bal}$, then there is no need for either cooling or heating the building.

For residential buildings (with fewer internal heat sources), the balanced outdoor temperature may vary from 10 to 18°C. As discussed before, this means that if the balanced outdoor temperature is 18°C, then a cooling system is required when the outdoor temperature exceeds 18°C. This implies that buildings need cooling not only during summer but also during spring and fall as well. If the building is well insulated (small UA) and/or internal loads are high, then from the energy balance equation (2), the balanced outdoor temperature will reduce leading to extended cooling season and shortened heating season. Thus a smaller balanced outdoor temperature implies higher cooling requirements and smaller heating requirements, and vice versa. For commercial buildings with large internal loads and relatively smaller heat transfer areas, the balanced outdoor temperature can be as low as 2°C, implying a lengthy cooling season and a small heating season. If there are no internal heat sources and if the solar radiation is negligible, then from the heat balance equation, $T_{out,bal} = T_{in}$, this implies that if the outside temperature exceeds the required inside temperature (say, 25°C for comfort) then there is a need for cooling otherwise there is a need for heating. Thus depending upon the specific conditions of the building, the need for either cooling system or a heating system depends. This also implies a need for optimizing the building insulation depending upon outdoor conditions and building heat generation so that one can use during certain periods free cooling provided by the environment without using any external cooling system.

THERMAL LOAD CALCULATION FOR THE TIIR BUILDING

Heat Transfer Analysis - In any building, heat is transmitted through external walls, top roof, floor of the ground floor, windows and doors. Heat transfer takes place by conduction, convection and radiation. The cooling load of the building is dependent on local climate, thermal characteristics of material and type of building. For cooling load calculation, there are many types of software such as DOE 2.1E, BLAST, Elite or HAP 4.3 available which use the transfer functions method and heat balance method. These methods require a complex and lengthy data input. Therefore, most of the designers do not use these methods. They prefer a more compact and easy method for calculating the cooling load of a building. A more basic version for calculating a cooling load using the transfer function method is to use the one step procedure, which was first presented in the ASHRAE Handbook of Fundamentals in the year 2005. This method is called the cooling load temperature differences (CLTD) method. In this method, hand calculation is used to calculate cooling load.

In the TIIR building there are total 19 rooms of four floors where air conditioning is required including auditorium, lecture rooms, meeting rooms, library etc. Each one of them is treated as separate system.

Design condition - The amount of cooling that has to be accomplished to keep buildings comfortable in summer and winter depends on the desired indoor conditions and on the outdoor conditions on a given day. These conditions are, respectively, called the “indoor design condition” and the “outdoor design condition”.

The cooling load of the TIIR building is based on 25^{0}C dry bulb temperature and 50% relative humidity Indoor design conditions.

The outdoor design conditions are determined from published data for the specific location, based on weather bureau or airport records. The outdoor design conditions of Rourkela is 43 ^{0}C DBT and Relative Humidity 46% for summer (month of May) and 36 ^{0}C DBT and 84 % RH for monsoon (month of July).

Overall heat transfer coefficient calculation - Commonly the building walls may consist of non-homogeneous materials for example hollow bricks, air gap and plaster. Heat transfer through these types of wall is quite complicated as it involves simultaneous heat transfer by conduction, convection and radiation. All material has different kinds of thermo-physical properties.

CONCLUSION

The cooling load calculation described in the present paper is simply based on the rule of thumb. It may be called a computer version of cooling load estimation form. But surprisingly enough it gives very reliable results, which are almost the same as those obtained by the sophisticated and costly commercial software developed and marketed by the renowned MNCs. It is very easy to use and requires quite few number of data input. It is also capable of being used as a good tool to make thorough investigations of different building parameters and its orientation before starting the construction.

The new idea for deciding the cooling load which includes the likelihood thickness function is introduced utilizing the ventilation heat gain as an case. Under this method, the proper sum of cooling load might be coherently decided utilizing the referred to combined thickness function as an apparatus for choice making. Specialists can now state a sum of cooling load by knowing the likelihood that the load will happen. This helps diminishing the danger in air conditioning system venture.

REFERENCES

- A Bhatia, HVAC Made Easy: A Guide of Heating and Cooling Load Estimation, PDH online course M196 (4PDH).
- Christian A., Gueymard and Thevenard D., “Monthly average clear-sky broadband irradiance database for worldwide solar heat gain and building cooling load calculations” Solar Energy, 2009; 83; 1998–2018.
- Foudaa A., Melikyan Z., Mohamed M.A. and Elattar H.F., “A modified method of calculating the heating load for residential buildings” Energy and Buildings, 2014; 75; 170–175.
- Hani H. Sait, “Estimated Thermal Load and Selecting of Suitable Air-Conditioning Systems for a Three Story Educational Building” Procedia Computer Science, 2013; 19; 636 – 645.
- Stoecker, W.F. and J.W. Jones, 1982. Refrigeration and Air Conditioning. McGraw Hill, Int. Edn.
- Suqian Y., Jiaping L., Ge Xiangrong and Xiang H., “The Research of Cooling Load and Cooling Capacity Calculation Methods of Spinning Workshop” Procedia Environmental Sciences, 2011; 11; 597 – 603.
- Suziyana M. D., Nina S. N., Yusof T. M. and. Basirul A. A. S., “Analysis of Heat Gain in Computer Laboratory and Excellent Centre by using CLTD/CLF/SCL Method” Procedia Engineering, 2013; 53; 655 – 664.

- White, J.A., “Simplified Method for Predicting Building Energy Consumption Using Average Monthly Temperatures”, Proceedings of the International Conference on Energy Conversion, August 1996,

- Yao, R., N. Baker, and M. McEvoy, 2002, “A Simplified Thermal Resistance Network Model for Building Thermal Simulation,” The Martin Centre for Architectural and Urban Studies, Department of Architecture, University of Cambridge, UK.