Mathematical modelling and analysis of HVAC system of modern Buildings using renewables for optimization of Energy consumptions in Indian Scenario

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***Abstract*— The advancement of technology in domestic comfort specially indoor circulation of conditioned air has resulted in an escalation of household energy consumptions in India specially in summer and due to extensive use of cooling load. Due to high demand for cooling, a country wide energy crisis is witnessed during this time. In this research, a solar water heating of a residential house using the abundant and universal sources is proposed for a residentials house in India for mitigating this energy shortage and for offering a sustainable solution to the problem. The paper presents a mathematical model of the house on TRNSYS simulation software along with the simulation results of coupling of the several components operating in parallel with the cooling systems. The results demonstrated that, the proposed model of household solar cooling system may be satisfactory used for a residential house or HVAC systems in Indian scenario. The system was modeled using TRNSYS software and its components to represent the various parts of the solar heating system. Assumptions, modelling of different components and their limitations of simulations have been depicted as per the requirement of the proposed research work.**

Keywords— Mathematical Modelling, energy efficiency, Solar water heater, TRNSYS software, TRNBuild, HVAC & optimization.

I. INTRODUCTION

There are different literature are available for the Building energy management system at which describes the usefulness of energy efficiency in building sector & how to optimize the efficiency to get the optimum values. Nowadays, energy has been known as one of the most important factors for forming and developing industrial societies [1]. For every residential building, it is the most important issue to effectively manage the energy as well as achieve higher occupant's comfort. The reason behind the fact is that the energy consumption increases rapidly with the passage of time and becomes more and more expensive and the user cannot compromise on his/her comfort. Therefore, the energy consumption minimization and user comfort maximization need to be balanced to achieve both goals. There are many proposals in the literature addressing the issue of user's comfort and energy consumption (management) with keeping different parameters in consideration [2,3]. it was found that a lot of scope is still prevalent in the improvement of energy efficiency through intelligent ways of using solar power. In Persaud of exploring the opportunity this paper presents an energy efficient HVAC based domestic solar cooling system in TRNSYS software in Indian scenario. The paper also proposed various methods of reduction of energy consumptions to optimize the energy efficiency of the building using solar water heater.

II. LITERATURE SURVEY

In recent era, the concepts of optimization of Building energy consumptions and user comfort level has plays an important role. There are various algorithm are used for addressing these building energy consumptions but some techniques are more useful to formulate different components and simulate how much energy that the building should consume. In this literature, using a proposed optimization technique addressing the energy consumptions in the building sector. Moreover, Building Energy Efficiency Optimization methos is also applied for evaluate the Effective Thermal Zones Occupancy. This research presents an innovative and low-cost methodology to reduce buildings' energy requirements through post-occupancy assessment and optimization of energy operations using effective users' attitudes and requirements & it is applied to optimized building energy operations which allow a reduction of primary energy requirements for HVAC, lighting, room-electricity and auxiliary supply. In research activities, it is clear that one of the most important challenges in this century in the world is energy crisis. On one hand, shortage of energy resources and its growing consumption and on the other hand, extreme usage of energy by different users has endangered future life of human and polluted the environment. In order to optimize energy consumption, one must, at first determine a set of consumption standards in different sectors based on the latest levels of technology and other factors affecting energy consumption. Energy efficiency in building stock has become a potential approach to accede sustainability in the built environment and a lucrative source for builders and investors that is discussed in

In this article, due to its definitive impact on energy consumption, building envelope plays a crucial role in the investment and the pattern of energy demands will change after the retrofit of the building. In this literature, Energy Plus has been selected as a tool for building information simulation. Particularly, the jEPlus optimization engine has been selected to optimize multi-objective problems using a genetic algorithm and carry out the energy-simulation. Another literature described in this paper energy management in residential buildings according to occupant's requirement and comfort is of vital importance and in this paper, Artificial bee colony (ABC) optimization technique is used here for maximizing the user's comfort and minimizing the energy consumptions simultaneously in the building energy consumptions. it is again mentioned that Optimization of Energy Consumption in the building Under the requirement of energy savings and emission reduction, building energy consumption, which occupies arising proportion of the total energy consumption in society has become the focus of energy conservation research.

From the above literature survey, it was found that a lot of scope is still prevalent in the improvement of energy efficiency through intelligent ways of using solar power. In Persaud of exploring the opportunity this paper presents an energy efficient HVAC based domestic solar cooling system in TRNSYS software in Indian scenario. The paper also proposed various methods of reduction of energy consumptions to optimize the energy efficiency of the building using solar water heater.

III. METHODOLOGIES OF PROPOSED RESEARCH

A. Performance of Energy Efficient Building modeling

Energy efficiency is the ability to reduce the amount of energy required to deliver various goods or services using less energy for heating cooling and lighting [4]. Energy efficient buildings starts from the building envelope, which includes energy efficient windows, insulation, foundation and the roof to appliances, lights and air-conditioning systems applies to space heating and cooling systems which are aided through the use of automated controls, ventilation, improved duct systems and other advanced technologies. Energy efficiency can also apply to water heating (i.e. solar water heater) when combined with water-efficient appliances and fixtures [5]. There are different methods targeting the decrease of energy consumption of buildings. Considering energy consumption in each phase of structuring is achieved with the analysis of building life cycle. In this respect the Building life cycle is divided into three main phases such as the prebuilding phase, building phase, and post building phase[6]

B. Methodologies of existing Building modeling techniques

The word Modelling comes from the latin word modellus. A model is a simplified version of something that is real. The methodologies used to test the whole building energy modelling and its energy management can be analyzed using three different Techniques, they are as follows,

1. White Box Modeling Technique or Open Box Testing Or Clear Box Testing
2. Black Box Modeling Technique or Close Box Testing Or Opaque Testing
3. Gray Box Modeling Technique or Translucent Testing or Gray Box Modeling = Black Box Modeling + White Box Modeling

C. Proposed architecture design work flow methodology

The proposed architecture is based on simulation & standard optimization techniques. The simulation technique used here are TRNSYS software and using the standard optimization technique one can optimize the energy consumptions and increase the comfortable part of user. TRNSYS is a complete and extensible simulation environment for the transient simulation of systems, including multizone buildings [8]. TRNSYS is a Transient Systems Simulation Program & this software is developed in 1974 by the University of Wisconsin Madison, USA and used by many researchers. TRNSYS is a simulation software for the thermal behavior of buildings and associated systems under dynamic condition [9]. In order to properly utilize the TRNSYS program, an ANSI standard FORTRAN 77 compiler is required. Users without a FORTRAN compiler may still run the program, but will not be able to modify existing components or add new components. It includes the Simulation Studio and TRNBUILD Software [7]

D. Development of HVAC based Domestic House on TRNSYS Software

This model type is useful for estimating heating or cooling loads for a residential house. Walls, factories, flat roofs, doors, and floors are included in this component. The building should be designed according to different dimension and their rating [10]. Also for the design concepts, various elements are incorporated into it & working accordingly. For the modelling purpose, some factors are usually used for designing the whole formation of building. The orientation, hemisphere, calculation (whether it is internal and external surface) and used by surface that have used in orientation place.

E. Implementation of the proposed HVAC based Solar water heater model in TRNSYS Simulation

For modelling the House and Its geometrical perceptions modelling is the best alternative for calculating the whole energy and corresponding indoor outdoor temperature, and some ageing factors like humidity thickness and much more are the required details of a residential building. For the overall progress of the building, one can used TRNBuild is the mechanism of TRNSYS where different types of factors are urgently needed for whole modelling purpose of residential house and also used different measurement for daily, weekly, yearly energy consumption. on the other hand, simulation diagram is the diagram where a model may be implanted with unlimited variations. The simulation diagram is

IV. MATHEMATICAL MODELLING OF SOLAR WATER HEATER

The Proposed system governing some mathematical expressions which is used for Daily, weekly, monthly & yearly energy consumptions in modern buildings using the domestic solar water heater. For better performance, the use of solar water heater is considered only to monthly energy consumption. The daily radiation on the collector system is formulated by the following equation,

$$\overline{H_T} = \overline{H}_b\overline{R}_b + \overline{H}_d(\frac{1+\cos\beta}{2}) + \overline{H}\rho_g(\frac{1\cos\beta}{2})$$

Where, $\overline{H}$ is the monthly average daily radiation on a horizontal surface, $\overline{R}$ is the monthly average ratio of the radiation on a tilted plane to that of a horizontal surface, ρ is the reflectance and β is the collector slope. The subscripts b, d & g denotes the beam, diffuse and ground respectively.

The monthly average absorbed solar radiation per unit area of the collector can be written in this way,

$$\overline{S} = \overline{H}_b\overline{R}_b(\overline{\tau\alpha})_b + \overline{H}_d(\overline{\tau\alpha})_d(\frac{1+\cos\beta}{2}) + \overline{H}\rho_g(\overline{\tau\alpha})_g(\frac{1-\cos\beta}{2})$$

where, $(\overline{\tau\alpha})_b$, $(\overline{\tau\alpha})_d$ $(\overline{\tau\alpha})_g$ are beam, diffuse and ground reflected terms of the monthly average transmittance-absorptance product respectively. The other are described as above.

The governing equation of collector will be obtained by [15],

$$(mC)_c\frac{dT_c}{dt} = A_cF_RS - (A_cF_RU_L - \dot{m}C_p)T_{ci} + A_cF_RU_LT_a - \dot{m}C_pT_{co}$$

where T, $\dot{m}$ and C_p are the temperature, mass flow rate and specific heat respectively. A, F_R and U_L are the surface area, heat removal factor and overall heat loss coefficient respectively. S is the absorb radiation per unit area of the collector. The subscripts c, I and o refer to collector, inlet and outlet respectively.

The equation governing the storage tank is given by as follows,

$$(mC_p)_s\frac{dT_s}{dt} + (\frac{1}{R} + \dot{m}C_p)_sT_s = \frac{T_a}{R_s} + (\dot{m}C_p)_fT_f + (\dot{m}C_p)_{HX}(T_{HXo} - T_{HXi})$$

where, R is heat transfer resistance of the storage tank itself. The subscripts S, HX and f refer to storage tank, heat exchanger and feed water, respectively. All other parameters are as previously defined.

The temperature of the heat exchanger outlet and collector inlet (temperature of the working fluid flowing inside the pipe connecting the storage tank to the collector after losing part of its heat to the ambient before entering the collector) are defined respectively by following relations as follows,

$$T_{HXo} = T_p - exp[\frac{-PLU}{(\dot{m}C_p)_{HX}}](T_p - T_{HXi})$$

$$T_{Ci} = T_p - exp[\frac{-PLU}{(\dot{m}C_p)_{HX}}](T_p - T_{HXo})$$

where, T_p is heat exchanger pipe wall temperature, P, L and U are wetted perimeter, length and heat transfer coefficient of the heat exchanger pipe, respectively. Other parameters are as described above.

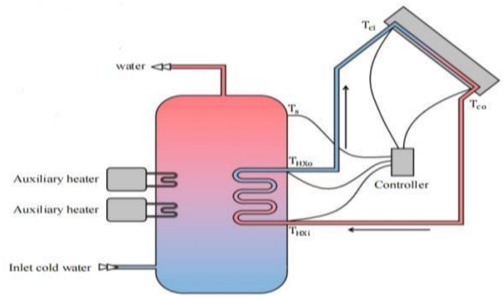


Fig.1: Proposed Solar water heater

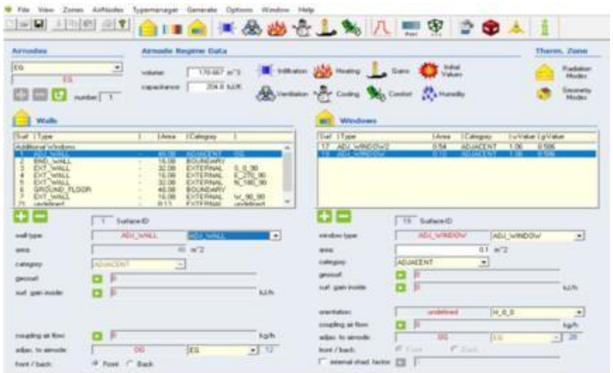


Fig. 2: TRNBUILD mechanism

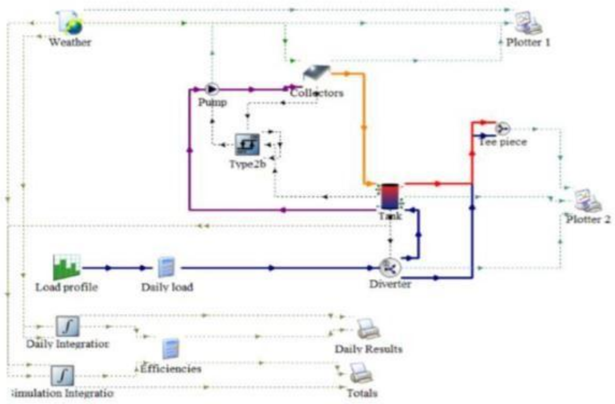


Fig. 3: Proposed model of Solar water Heater in TRNSYS

F. Modelling and Simulation of an Energy efficient building in Western Countries using TRNSYS

The improvement of the building energy efficiency is achieved by reducing the energy consumption and emissions. Since buildings thermal behavior depends on different variables, which complicates the control of predicting energy consumption, the use of buildings thermal simulation models which are based on the building energy balances for each zone is what fits best. To estimate the heating and cooling load and the annual energy consumption, the air temperature is needed. In order to have an overview on the ambient temperature fluctuations, the two followings' graphics represents respectively the days showing hourly values of the ambient temperature, the daily extreme and the daily mean values of the ambient temperatures [11]. The simulation results also give the status of Energy consumptions are very poor compared to Indian scenario.

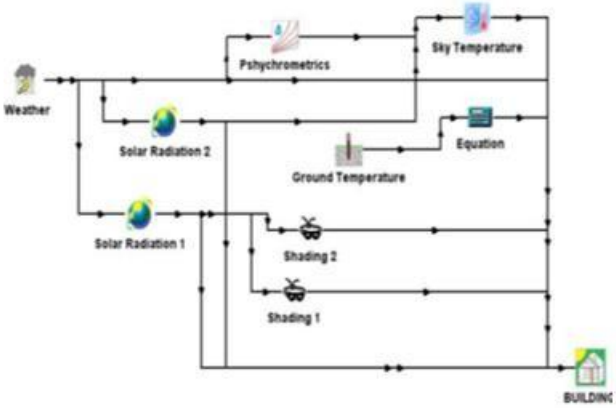


Fig. 4: Simulation Model of Building design in European countries in TRNSYS software

the simulation results are,

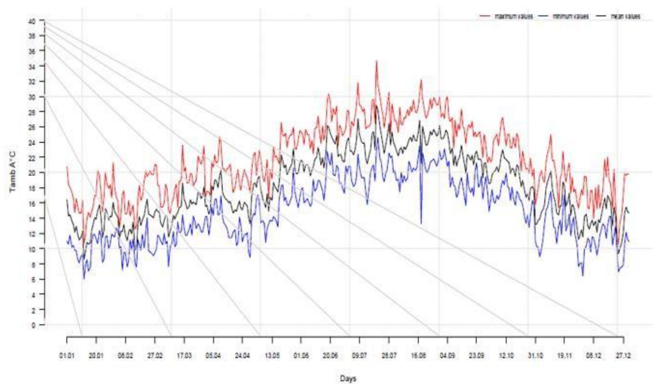
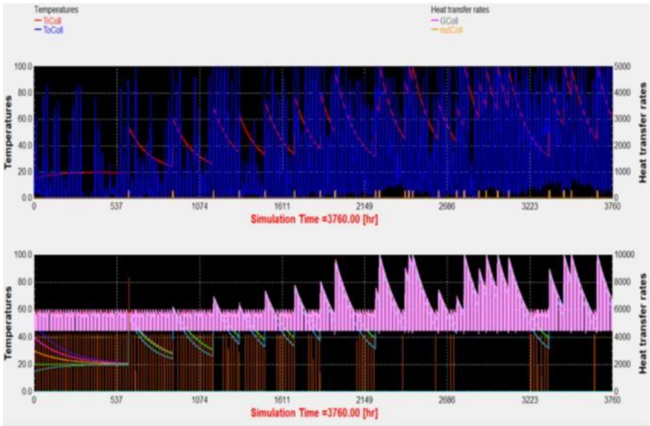


Fig. 5: Simulation results of European countries in TRNSYS software

III. RESULTS & DISCUSSIONS

G. Simulation Results of the Proposed model (Indian Scenario) and discussions

After components are linked properly in simulator, the output results are viewed in terms of simulation output. The figure of output on different parameters are collected together and that's why the discussion are very necessary.



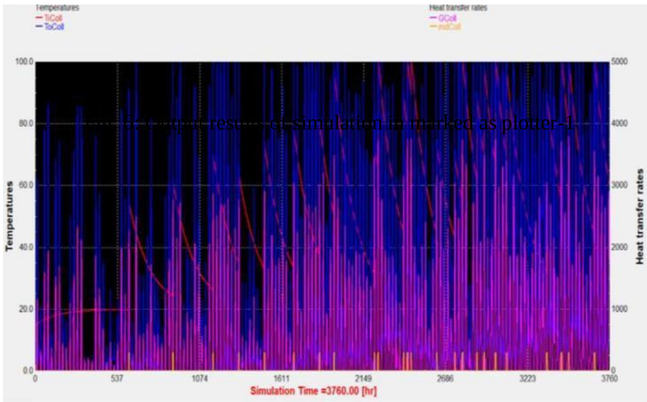


Fig. 6: Output results of simulation in marked as plotter-1

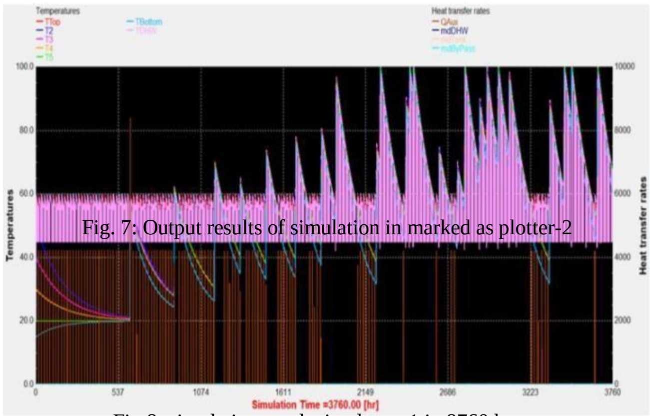


Fig. 7: Output results of simulation in marked as plotter-2

Fig.8: simulation results in plotter-1 in 8760 hours

The solar energy system simulation is transient in nature; therefore the chances of uncertainty and error in simulation are very high. Initially numerical methods were deployed widely in design of solar water heater system but after inception of computer, lengthy and repetitive calculations were obsolete. Numerous simulation tools based on different platform and assumptions have been developed. Extensive research work focused on different components, system configuration and operating conditions are carried out. The simulation depends upon the programmer; how accurately and precisely the model of consisting components have been designed.

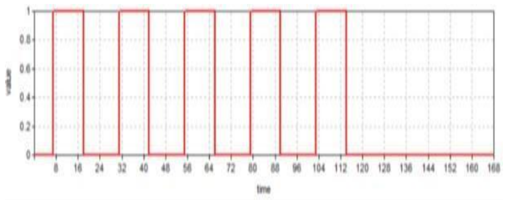


Fig.9: Daily energy consumptions in Building Sector

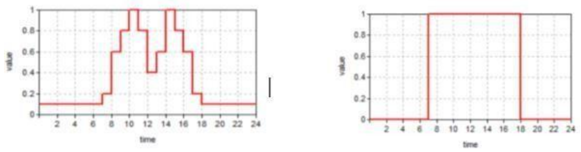


Fig.10: Weekly energy consumptions in Building Sector

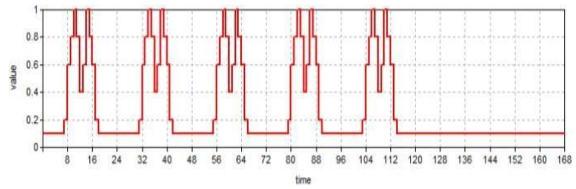


Fig.11: Yearly energy consumptions in Building Sector

Current version of TRNSYS 2017 is a result of constant improvement, regular Updation inclusions of new components and governing parameters. Its modular approach and open-source code facilitate the user to customize and develop the model as per requirement. However, it includes most of the parameters and components are provided to include and modify to suite the requirement [12].

IV. COMPARATIVE STATEMENTS OF PROPOSED LITERATURE

It was found that when we compared the energy consumption between two regions or two scenarios, the energy consumption by daily, weekly monthly and yearly are far better to western regions. Using TRNSYS software we can visualize the different graphs related to this comparative analysis. However, solar energy system simulation is transient in nature; therefore the chances of uncertainty and error in simulation are very high. Current version of TRNSYS 2017 is a results of constant improvement, regular Updation inclusions of new components and governing parameters. Its modular approach and open source code facilitates the user to customize and develop the model as per requirement. However, it includes most of the parameters and components are provided to include and modify to suite the requirement

V. FUTURE SCOPE

Fast growing in solar energy market has been observed worldwide, advance technologies are being introduced in this area. Comprehensive up-gradation of simulation tools to predict more realistic results is need of the day. it is still a thrust area with agenda of accuracy improvement, adding new technologies and report management and cloud application etc. regular updates of simulation are required to account for change in climate, occupants' behavior and technology advancement. Due to dependency on geographical variables, simulation tools developed and validated locally may serve the purpose in better way. instead of going with a single simulation tool, simultaneous analysis of same system on different programs is recommended for future way.

VI. CONCLUSIONS

Simulation of solar water heater includes the transient as well as dynamic parameters. Simulation of SWH depends upon the several factors and many of them are beyond control. current version of TRNSYS 2017 has undergone of constant improvement and development. The quality of results depends upon the degree of accuracy and details considered during modelling. Simulation may be used in best way if acquired through series of experiments is used to train the software accurately [13]. In general, the simulations of solar systems and especially simulations with the TRNSYS program. In the drawbacks of this approach is the effort required to learn and use the program effectively and its cost [14].

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