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Energy Efficient Design of Solar water heater for Improvement of Energy Efficiency of Smart Buildings Using TRNSYS in Indian Region

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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 modelled 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 - HVAC, optimization, Solar water heater, TRNSYS software, TRNBuild

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I. INTRODUCTION

Energy is a prime requirement of modern society. However, the use of energy from finite fossil fuels is recognized as changing the global climate through the excessive release of greenhouse gases If it is solar energy, then this energy has been an integral part of life on earth. Most forms of energy we use, including fossil fuels, come directly or indirectly from the Sun. In [1] Fossil fuels, even though non are derived from solar energy and stored in the earth. In India, from buildings consume 47% of the primary energy, while industry and agriculture account for 28% and transportation 25%. In buildings 2/3rd of the energy need comes from dwellings and the remaining 1/3rd comes from commercial activity. In this work our aim was to use a dynamic numerical simulation software to reduce by design a house energy consumption of the so-called Energy plus house. 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. First organized the different modelling techniques of energy efficient building regarding this issue (Section-2), this paper also says different Methodologies of existing building modelling (Section-3), Introduction and applications Solar Water Heater (Section-4). Moreover, this paper also represents The TRNSYS (Simulation Studio And TRNBUILD) Software (Section-5) and Implementation of the Proposed HVAC based Solar water heater model in TRNSYS in next section (Section-6). after the implementation Simulation Results of the Proposed model is also discussed (Section-7) and finally its conclusions (Section-8)

II. MATERIALS AND METHODS

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. It also means incorporating different methods to ensure that energy is conserved. Energy-efficiency buildings applies to everything 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. The concepts of energy efficient building has immediately applies on regulations [2] , economics, energy demand, and the environment & compare building energy performance criteria for an energy efficient building.

There are different methods targeting the decrease of energy consumption of buildings. In this respect we need to know the life cycle of building. Building life cycle is divided into three main phases such as the prebuilding phase, building phase, and post building phase.

III. DESIGNING METHODS OF ENERGY EFFICIENT BUILDING

There are lots of designing method available, out of them some important points are as follows,

3.1 Energy-efficient methods in the prebuilding phase

This phase includes the construction space is to be built, the building design, the building materials, obtaining raw materials for building material, manufacturing, and transporting them. Therefore, for design the efficient building modelling, we are analyzed Solar water heater & Pump for the design of energy efficient HVAC based Residential building using TRNSYS software

3.2 Energy-efficient methods in building phase

Building phase includes the construction and usage processes of building, building phase is possible with preferring building techniques consuming less energy and using energy-efficient equipment. Using energy efficient bulbs [3] and energy-efficient appliance, Lighting controls & High-efficiency heating, ventilation, and cooling equipment Heating ventilating air conditioning (HVAC) systems extremely influence energy consumption in buildings. highly efficient building envelopes reduce the need for heating and cooling systems. Good and intelligent designed buildings can reduce the need for HVAC systems.

3.3 Energy-efficient methods in post building phase

The post building phase includes the demolition of building, recycling, and destruction of it. In this phase, it is important to recycle the building materials and compositions used in the buildings and reuse buildings.

3.4 Methodologies of existing Building modelling techniques

The Methodologies used to test the existing 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

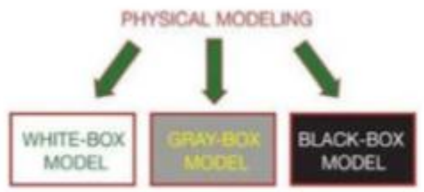

Figure1: Classification of modelling techniques

The white box modelling technique is used to model building components, sub-systems to predict whole buildings and their sub-systems behaviors, such as their energy consumption and indoor comfort, Black box model is used to capture the correlation between building energy consumption and operation data. It is also widely applied in existing studies to determine building control strategies to reduce energy [4] consumption and energy cost and lastly grey box modelling is a hybrid models that use simplified physical descriptions to simulate the behavior of building energy systems.

IV. DESIGN OF PROPOSED 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,

$$\overline{H}_T = \overline{H}_b \overline{R}_b + \overline{H}_d \left(\frac{1+\cos\beta}{2}\right) + \overline{H} \rho_g \left(\frac{1 \cos\beta}{2}\right) \text{--------(1)}$$

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,

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

where, $\overline{(\tau a)}_b$, $\overline{(\tau a)}_d$ $\overline{(\tau a)}_g$ 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],

$$(mC)_c \frac{dT_c}{dt} = A_c F_R S - (A_c F_R U_L - \dot{m} C_p) T_{ci} + A_c F_R U_L T_a - \dot{m} C_p T_{co} \text{-------(3)}$$

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,

$$(mC_p)_s \frac{dT_s}{dt} + \left(\frac{1}{R} + \dot{m} C_p\right)_s T_s = \frac{T_a}{R_s} + (\dot{m} C_p)_s T_f + (\dot{m} C_p)_{HX} (T_{HXo} - T_{HXi}) \text{------(4)}$$

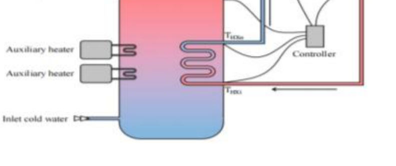

Figure 2 Proposed Solar Water Heater

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,

$$T_{HXo} = T_p - \exp\left[\frac{-PLU}{(\dot{m} C_p)_{HX}}\right](T_p - T_{HXi}) \text{---(5)}$$

$$T_{Ci} = T_p - \exp\left[\frac{-PLU}{(\dot{m} C_p)_{HX}}\right](T_p - T_{HXo}) \text{---(6)}$$

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.

V. TRNSYS (Simulation Studio and TRNBuild) Software

TRNSYS is a Transient Systems Simulation Program, it is one and only best simulation technique for building energy simulation and its energy management. TRNSYS is a complete and extensible simulation environment for the transient simulation of systems, including multi-zone buildings. It is an open modular structure with open-source code which simulates all sectors of an energy-system except the transport sector [5]. TRNSYS is a simulation software for the thermal behavior of buildings and associated systems under dynamic conditions. In order to properly utilize the TRNSYS program, an ANSI standard FORTRAN77 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. The TRNSYS is a simulation program primarily used in the fields of renewable energy engineering and building simulation for passive as well as active solar design.

5.1 TRNSYS Software for Solar Water Heater

Several simulation tools have been used for analyzing the solar water heater. popularity and adaptability of TRNSYS in simulation of SWH is significant. Major components of a solar water heater are solar collector system, storage tank, pump (in forced circulation), controller and an auxiliary heater. Heating in SWH occurs during sunshine hours only. In order to get the factual results any of the experimentation work on SWH should been carried out throughout day as well as in various climate conditions. Research in SWH involves iterative variations in input parameters and its effect on output parameters consequently. The study reveals that, all type of solar water heater e.g., flat plate collector, concentrated type collector, evacuated type collector, is simulated successfully for design and optimization and performance analysis take Solar irradiance 1200 watt/m^2 , tilt Angle or slope is 45^0 and azimuth angle is 30°

5.2 Design of HVAC based Residential House on TRNSYS Software

For modelling a residential house, the model type-56a is useful for estimating heating or cooling loads for a residential house. The house consists of different interior & exterior components, such as Walls, factories, flat roofs, doors, and floors are included in this component. The houses consist of a ground floor, an upper floor and a loft. The large window area allows sun radiation to heat the building. In addition, the house each have a roof window, which makes effective airing possible during the summer season [6]. The set of equations for heat transfer from and within the zone are formulated in a matrix and solved in a computationally efficient manner each simulation time step. In order to describe a zone using this component, the user specifies separate sets of parameters and inputs describing the internal space, the walls (also floors and ceilings) windows and doors. The walls are modeled using the transfer function approach. Normally, a controller is used in conjunction with this mode to command the heating or cooling equipment. The following is the modelling of a residential house of two storied constructions in Asansol city. 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. We choose the hemisphere as a northern side but generally for the standard data format. of orientation, the location of the proposed building has to be defined As a Northern and Southern side. The orientation is the following, **1.)** H_0_0 **2.)** S_0_90 **3.)** S_0_25 4**.)** W_90_90 **5.)** N_180_90 **6.)** N_180_25 **7.)** E_270_90 here, E-East, W- West, N-North, S- South Direction. For modelling purposes, the inputs and outputs data are required for calculating the inner compartments of the residentials building.

5.3 TRNBUILD Mechanism for modelling the House and Its geometrical perceptions

The building geometry of given vertex and its internal and external shading geometry of residential components used. Therefore, this 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

Figure 3: Standard file of TRNBuild

It is the overall progress of modelling of building and TRNBuild is the mechanism of TRNSYS where different types of factors are urgently needed for whole modelling purpose of residential house. It is observed that, in TRNBuild mechanism, a Scheduled type manager where daily weekly and yearly consumptions are noted down

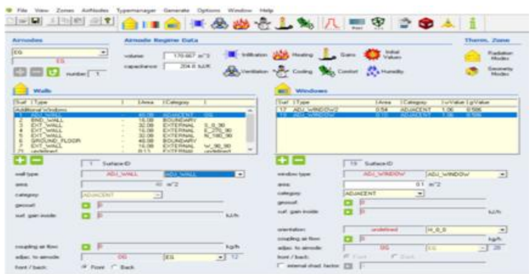

Figure 4: TRNBuild mechanism (on TRNSYS)

VI. Modelling & Implementation of The Proposed HVAC Based Solar Water Heater Model In TRNSYS

Models may be mathematical, physical or logical representation, of a system or process. other hand, Simulation is the representation of a system or process. Though simulation, a model may be implanted with unlimited variations. The tool that executes the simulation is called a Simulator [7,8].

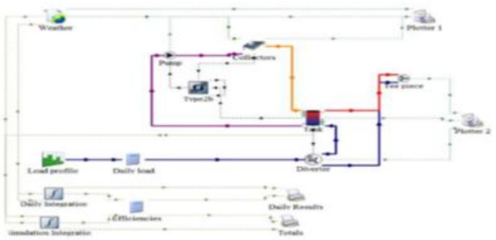

Figure 5: Proposed model of Solar water Heater in TRNSYS

In the proposed research, the different components are arranged parallelly into the simulation studio & after that the proper implementation is carried out. All the components are arranged together by linking them properly and the components that are using are the library of system components.

The inputs are the Load Profile and Daily Load, Heat Exchanger, Weather File, Collector System, Controller and hydraulics etc. The outputs are the results of any simulation e.g., Online Plotter, Printer, Histogram, Spreadsheet, etc. The Online Plotter enables design, alternations, tuning and customization simultaneously, here Plotter-1 and Plotter-2 is giving the output results.

6.1 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.

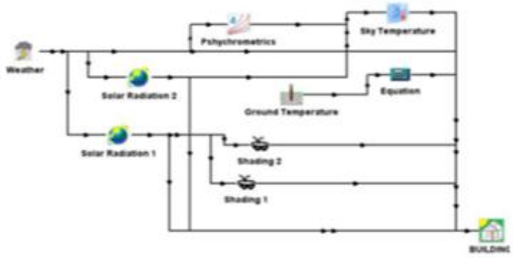

Figure 7: Simulation of European countries in TRNSYS software

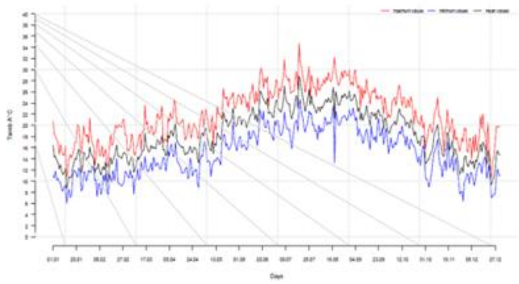

Figure 8: Simulation results of European countries in TRNSYS software

VII. RESULTS & DISCUSSIONS

Mainly Simulation Results of the Proposed model (Indian Scenario) here After components are linked properly in simulator, the output results are viewed in terms of simulation output. The figure of output on [10] different parameters are collected together and that's why the discussion is very necessary,

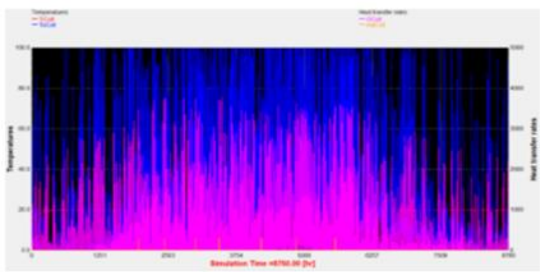

Figure 9: Output results of simulation in marked as plotter-1

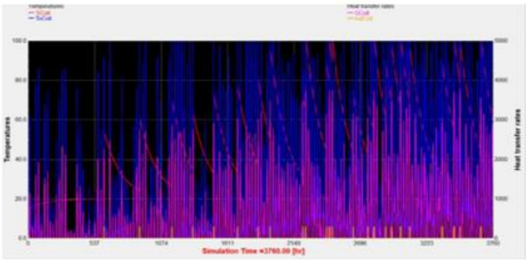

Figure 10: Output results of simulation in marked as plotter-2

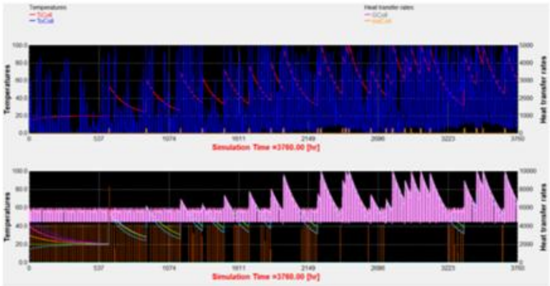

Figure 11: Output results of simulation in marked as plotter-1 in 8760 hours

The solar energy system simulation is transient in nature; therefore, the chances of uncertainty and error in simulation are very high. 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. Current version of TRNSYS 2017 [11] is a result 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.

VIII. CONCLUSIONS

Simulation of solar water heater includes the transient as well as dynamic parameters. Diurnal and seasonal variations in solar insolation and draw profile affects its performance substantially. Simulation of SWH depends upon the factors like geographical locations, weather occupant behavior, operating conditions, consistency and coherency of data and human errors etc. and many of them are beyond control. Many assumptions made during its modelling pertains to mass flow rate, draw pattern, and stratification.

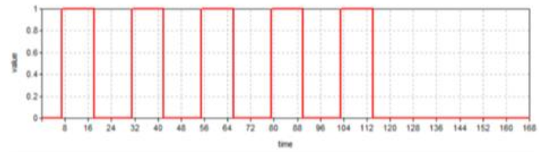

Figure 12: Daily energy consumptions in Building sector

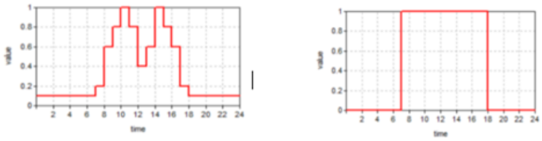

Figure 13: Monthly energy consumptions in Building Sector

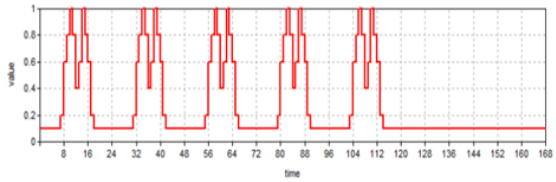

Figure 14: Yearly energy consumptions in Building Sector

Heat capacity of collector, direction of heat flow etc. 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. In general, the simulations of solar systems and especially simulations with the TRNSYS program cultivates a change in culture in a company manufacturing solar systems from being reactive to become proactive [12,13]. It is highly encouraged that this approach should be adopted by manufacturers of solar systems who would like to increase their potential, as this has been proved to be the major contribution in the pursuit of excellence. In the drawbacks of this approach is the effort required to learn and use the program effectively and its cost.

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