ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and Analysis of Solar Water Heater

Challa Mohan Brahma Reddy
M.Tech,
Department of Thermal Engineering,
Malla Reddy College of Engineering.

Dr.V.V.Prathibha Bharathi
Professor,
Department of Thermal Engineering,
Malla Reddy College of Engineering.

ABSTRACT:

Renewable sources of energy are anticipated to play a significant role in energy generation in Ireland in the future. Ireland has a lack of indigenous fossil fuel therefore making the production of energy expensive and environmentally unfriendly. One such renewable source of energy that can fulfill this role is commercial solar water heating. Solar water heating has not been popular in Ireland to date and this research aims to establish if the software used in the design of the systems is a contributing factor to this. An extensive literature review was firstly carried out to establish the main design issues of solar water heating systems. Results of questionnaires sent to designers and installers of the systems indicated that Tsol and Polysun were the main simulation software's used in Ireland. The research concentrates on running simulations on two case studies, Cloughjordan Eco Village in Co. Tipperary and Bewleys Hotel Dublin Airport. The results of the simulations indicate that the tilt angle of the collectors in both case studies was not installed at the optimum angle. The results also indicate for when the space heat demand is greatest in Cloughjordan Eco Village an increased angle to 60˚ would provide a higher output in the heating season of April to October. The two simulation software's used in the research were compared and analysed. Polysun proved to be a more complete package with an option to create custom hydraulic diagrams to exactly match the system being simulated. The weather file used in Polysun also interpolates the location of the system rather than using nearby weather station data. It was concluded that some simulation software's such as Polysun do offer an optimised design solution for solar water heating systems in Ireland but careful consideration must be given to select one that does.

INTRODUCTION:

The need for renewable energy has been recognized globally as populations swell and the demand for fossil fuels increase. The depleting resources of fossil fuels and increased costs have led to the development of new and technologically advanced renewable energy sources. With the government committed to targets set by the E.U. renewable sources of energy will slowly replace the use of some fossil fuels. Ireland has a lack of indigenous fossil fuel therefore making energy production expensive and environmentally unfriendly. The country as a whole is over reliant on imported gas, coal and oil. Solar water heating production has become more appealing in recent years on a global level; however it has been less popular in Ireland to date on commercial projects. With the over reliance on fossil fuels for energy production, the Irish Government have realised the need to research and develop this area further. The National Renewable Energy Action Plan sets a target that 16% of Irish energy sources will be from renewable sources by 2020. This strategy also includes a renewable heat market penetration target of 12% by 2020 (Government White Paper, 2007).

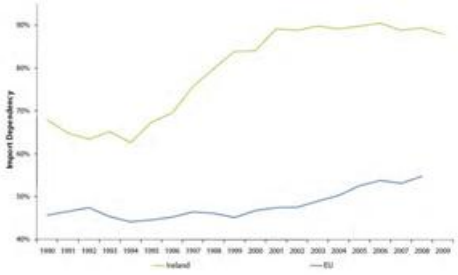

Fig. Irish Dependency on Imported Fossil Fuels compared to EU average (SEAI, 2008)

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Bewley's Hotel Case Study:

The Bewley's Hotel near Dublin Airport is the newest hotel in the Bewley's Hotel Group and was opened in June 2006. The designers of the hotel and the client want to put energy management first and foremost in the design of the hotel. It was estimated at the design stage that energy consumption for hot water, for baths, showers, kitchen etc, would contribute to approximately 50% of the hotel's total energy use.

Fig. Solar Panel Installation Bewley's Hotel

This discovery prompted the design team to incorporate systems that could lower the costs of the hotel's hot water production. The most popular and feasible option was to install a large scale solar water heating system which was the largest in Ireland at the time of construction. The large scale system includes 56 solar panels or 308m^2 of total collector area on the roof of the hotel (SEAI, 2007).

Drain-Back System:

The system designed by Zen Renewables supplies part (30-40%) of the hot water demand of Bewleys Hotel. The system is designed to be a pre-heater system with two 5000 litre solar storage cylinders. The first cylinder on the loop is a combined drain-back / solar heat storage and is joined in a closed drain-back configuration with the collector field on top of the hotel. The water in this primary collector circuit is pure water in a closed circuit and does not need treatment like other systems which contain glycol. In the second cylinder water is fed through a heat exchanger which contains pre-heated water from the mains supply (ZEN Renewables, 2008).

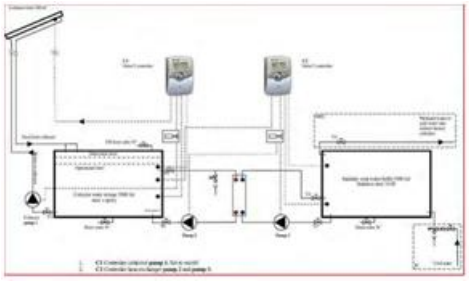

Fig. Hydraulic diagram of Drain-back system

The pre-heated hot water is supplied to 3 x 5000 litre indirect gas heated cylinders in order to guarantee the hot water supply at all times for the hotels occupants. The collector field is mounted on the 7th story roof of the hotel. With the tall height of the hotel the steel frame support construction and collectors are engineered for the maximum wind loads for the height and location. The advantages of the drain-back concept as detailed in Chapter 2 is that there are no anti-freeze additives required and the system is inherently safe for overheating situations or power failures. Furthermore the drain-back concept has minimum maintenance requirements, whilst the system performance is still very high (Zen Renewables, 2008).The Bewley's hotel building at Dublin Airport faces slightly east of pure south.

As the effect on performance was minimal, the solar collectors were oriented parallel to the façade of the building and not directly south, for visual reasons. The estimated cost of the solar system was €210,000 approximately 25% of this was obtained from SEAI for the purchase and installation of the solar panels. The SEAI estimated in a case study on the project that the system would contribute 198,000 kWh of solar energy to the heat demand of 466,000 kWh. This represents a CO2 emissions saving of 46 tonnes per year. This solar energy contribution equates to €15,000 of annual fuel cost savings in gas with a payback of 10 years (SEAI, 2007). These figures will be evaluated in the findings chapter where a simulation of the system is run.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

District Heating System:

In Cloughjordan Eco-Village, all space heating and hot water are provided by a solar assisted district heating system, owned and run by the not-for-profit Cloughjordan Ecovillage Service Company. Two high-efficiency 500kW boilers fired with wood-chip (waste from a Midlands sawmill) are the main heat source. The biomass boilers are also backed up by 512 sq metres of ground mounted solar panels. Both sources supply hot water into well lagged distribution pipes, which provide a metered supply of heat to a heat storage tank in every home. This tank gives the householder complete control over the distribution of heat. The system has received substantial grant funding from the SERVE project (section 4.6.4), and SEAI's House of Tomorrow programme. The plant was first fired up in October 2009 however the ground-mounted solar array has not been functioning correctly since then (Comhar, 2011).

Fig. Ground Mounted Solar Array

The 512 m^2 of ground mounted flat plate solar collectors were supplied by Carey Glass. The collectors (Fig. 3.4) are arranged in nine rows, with five rows of eight number panels, one row of seven panels, two rows of five panels and one row of four panels. The solar array is orientated due south with an inclination of 30˚. The collectors feed a 17,000 litre buffer tank through a heat exchanger with a minimum return temperature of 58˚C. If the temperature does not equal or exceed this figure the solar output will not be useful to the district heating circuit. Origen Energy Ltd in conjunction with Polytherm Heating Systems Ltd designed and supplied a complete solar piping system, to remove the heat from the solar field and transport it back to the energy centre. This was done through the utilisation of a special preinsulated piping system, supplied from Brugg piping systems, known as Casaflex. Casaflex is made from corrugated stainless steel and has a very high temperature and pressure resistance. It can operate up to 180˚C and has a maximum operating pressure of 25 bar (Origen, 2012).

Methodology

Case Study Research:

According to Fellows & Liu (2008 p.111) "Case study approaches facilitate in-depth investigation of particular instances of a phenomenon. Those instances may be selected in a number of ways to be representative of general cases, bespoke cases and random cases. Normally because only a small number of cases are studied and the studies are in-depth, the purpose is to secure theoretical validity, rather than the statistical validity required of surveys". The case studies chosen for this research are the two largest commercial solar water heating systems in Ireland, Cloughjordan Eco Village and Bewleys Hotel Dublin Airport. The scale of these systems should provide a good indication of the performance of the commercial systems in the Irish climate and secure theoretical validity for the hypothesis.

Simulation Research:

According to Martinez & Ioannou (1999 p.267) "Quantitative simulation research is founded upon mathematics, probability and statistics. Simulation studies attempt to derive a semantic content from models which represent actual systems". Morgan (1984) suggests a variety of purposes for simulation:

- Explicitly mimic the behaviour of a model
- Examine the performance of alternative techniques
- Check complex mathematical/analytic models
- Evaluate the behaviour of complex random variables, the precise distributions of which are unknown

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The results of the survey sent to the solar water heating system installers will denote which software packages will be used in this research. The system installers will be sent a questionnaire asking which software they use in their professional practice and what were the reasons for choosing that software package. The questionnaire will also ask what the respondents feel are the limitations of the software which will help in identifying if the software is suitable to achieve the objectives of the dissertation. Two software packages will be chosen from the results of this questionnaire and will be used for the simulation research in this dissertation. The performance of software packages will also be analysed and compared whilst carrying out the objectives.

Solar Output Temperature:

The results of the simulation on the predicted output were used to establish the predicted temperature of the collector outflow. In the case of Cloughjordan the return temperature of the District Heating System is 58˚C and the output from the solar array must equal or exceed this temperature to contribute to the buffer tank. The results of the simulation give the predicted temperature of the collector for each hour of the year. The percentage of time the output of the collector is useful is then quantified and representative figure is given for the actual output to the system. In the Bewleys Hotel case study the optimum temperature of the DHW is 65˚C without any top-up of heat from the gas fired heating cylinders. A frequency table will be compiled from the results of the simulation to quantify how often this temperature and above is achieved.

Heating Season Contribution:

In the Cloughjordan Eco-Village case study the collectors are currently installed at an orientation facing directly south with an inclination of 30˚. As described previously simulations will be carried out changing the orientation and the inclination for each. It should be noted that the solar assisted district heating system in Cloughjordan provides space heating for the houses in addition to domestic hot water.

This fact equates to there being a higher heat demand in the winter than the summer due to the cold winter in the Irish climate. This research will establish if a different inclination would be suitable for the higher demand in the winter than the current configuration. The collector temperature will also be analysed giving the percentage of time that the temperature exceeds 58˚C for each orientation and inclination. It was also established from the Literature Review that it is widely accepted that the optimum inclination of the collector should be equal to the latitude of the location the collector is situated. This research will investigate if that is true for the case studies chosen.

CONCLUSION:

Based on the literature review and findings of the primary research the following conclusions can be drawn from the dissertation. Each conclusion will be dealt with in reference to the objectives listed to reach the aim of the dissertation. The first objective in this dissertation was to simulate the predicted output using Tsol and Polysun, of the solar array on both case studies and compare both software's for accuracy and usability. In the case of Cloughjordan Eco Village, the comparison of the results from both Tsol and Polysun to the previously published research by (Monaghan, 2011) indicated that Tsol had a very similar overall output to IES VE that was used in that study. Further examination of Tsol and IES VE indicated that the system being simulated could not be replicated verbatim for the systems simulated in IES VE. Tsol had preloaded systems that had to be chosen as a best match. In the case of IES VE a standard system is incorporated with no choice of any other system. The weather data that was used for the simulations was taken from the nearby weather station in Birr for Tsol and IES VE but in Polysun the location of the system could be set using a GPS mapping system and weather data was interpolated for the chosen location. It was for the reasons just outlined that the author of this dissertation concluded that results of the Polysun simulation software of both case studies was deemed to be more accurate.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

REFERENCES:

1. Arizu, D. Balaya, P. (2011) "Direct Solar Energy - IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation" United Kingdom: Cambridge University Press.

2. Armstrong, S. Hurley, W.G. (2010) "A new methodology to optimise solar energy extraction under cloudy conditions" Renewable Energy, 35, pp 780-787.

3. Boyle, G. (1996) "Renewable Energy – Power for a sustainable future" Milton Keynes: Oxford University Press.

4. CIBSE (2007) "Solar Heating Design & Installation Guide" Malta: Print Solutions Partnership.

5. Comhar (2011) "Community Renewable Energy in Ireland: Status, barriers and potential options" Available at: http://www.comharsdc.ie/_files/2011-12-07_CommunityEnergyIrelandFinal_rpt.pdf (Accessed 4th August, 2012)

6. Darling, D (2012) "The Encyclopedia of Alternative Energy and Sustainable Living" Available at: http://www.daviddarling.info/encyclopedia/E/AE_evacuated_tube_collector.html (Accessed 5th August, 2012).

7. Davis, P. (2006) "Group effort: energy efficiency, cost reductions and integrating renewables with district heating" Construct Ireland, (2), pp42-47.