©2017 Published in 5th International Symposium on Innovative Technologies in Engineering and Science 29-30 September 2017 (ISITES2017 Baku - Azerbaijan)

Hot Water Production by Using Solar Energy in Heat Substations

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Abstract

It is possible to determine and evaluate the total energy usage of buildings for each independent unit in the central heating system. The total energy spent for heating and hot water supply is different for each independent unit. However, a single bill is generated for the heating device and water consumption and so it is divided equally used per individual unit in the absence of substations. It is known that these stations work primarily in use water. Utilizing solar energy to provide utility hot water is quite advantageous as another application. The adaptation of solar energy systems to these substations will be an advantage for both systems. With this system connected to the station pipelines, the heat exchanger temperature will be kept high. Thus, the additional energy costs will be eliminated or will decrease, depending on the requested water temperature for the usage hot water. In addition, the warm-up time will be reduced and thermal comfort will be ensured.

Key words: Substation, Exchanger, Central Heating

1. Introduction

The demand for energy in the developing and growing world is increasing day by day. Due to limited energy resources, efficient use of energy remains an important issue. The need for energy throughout the world requires energy saving schemes as well as research and development of alternative energy sources. 40% of the main energy consumed in Europe and in the world is occupied in the building sector. For this reason, the Energy Efficiency Directive is put into force and aims to save up to 20% by 2020 [1]. When evaluated as sectoral, the energy consumption in the construction sector has an important share in total energy consumption. This connection will be in place to evaluate the energy consumed for central heating and utility hot water supply. In addition to using energy efficiently for heating, it is important to develop environmental technologies as well.

Generally, buildings that are considered as habitats should also be defined as machines from a certain point of view. Thermal evaluation is essential for these machines to be transformed into living spaces. There are three main methods of heating buildings: hot air, hot water and steam heating. Work done in the last half century has removed the suspicions about this heating system and made it possible to use it in architectural, engineering and social sense [2]. It is mostly used in hospitals, schools, theaters and public buildings. In other buildings, individual heating techniques and devices are used. However, with the enactment of the Energy Efficiency Law, which became effective in 2007, it became imperative for the centralization of heating for many buildings [3]. The conservation and efficiency of energy is one of the most important components

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of Turkey's 2023 strategic objectives. Energy efficiency studies aim to reduce the energy intensity by 20% [4].

With the importance of central heating, new technologies have gained momentum for efficient energy use at the buildings. In particular, the applications of heat substations that meet the heating and usage hot water requirements of independent units are one of them.

In buildings, the production of heat from a single center and the heating of the entire building with pipelines cause injustices in the use of energy among independent units. Despite the dissipation of approximately equal heat energy for each individual unit, equal thermal comfort is not achieved due to the physical conditions of the building. However, the first and last floors where heating is often inadequate and the apartments on the cold front are equally shared with energy costs. With the application of a heat substation installed in independent units developed as a new technology, this problem has come to an important extent. In this application, energy consumption and heating conditions are evaluated together and a separate usage fee is created for each independent unit.

2. Materials and Method

One of the oldest and simplest methods of generating domestic hot water is the use of solar energy. This process is basically based on the principle that the solar radiation is collected and the temperature of the water used is increased. Nowadays, in the systems that produce hot water with solar energy, the water heated by the solar collector is collected in a storage and sent to the places of use on demand [5]. In this study, this simple but effective system was evaluated at the heat substations considered as a new technology.

The primary energy source for heat substations is the central heating device or central geothermal energy line. Hot water from the central heating floor station makes it possible to provide hot water for use as well as heating the stand-alone unit. To this end, heat exchangers are used to provide hot water production at the stations. The central feed water passing through the 5-way valve, which is the base part of the heat substation, is sent to the radiators in the stand-alone unit (apartment, workplace, common area, etc.) or to the heating pipes. The water returning from the heating system is sent to the central heating point via the substation. This is how the heating process occurs [6, 7].

Demand for domestic hot water is determined by opening the taps and creating a water flow. The 5-way valve, which senses the use of water, directs the central supply line to the heat exchanger. The mains water flows into the heat exchanger simultaneously. In this section, the warming water is sent to the places of use. After the heating operation is performed, the central feed water is sent to the central heat point via the return line. The heater installation return and the exchanger outlet water combine at the heat station to form the return line. The total energy consumption is calculated by means of the thermometer on the return line. Total consumption is billed by heating the zone and determining the amount of energy consumed by the heat exchanger [8, 9, 10].

Water coming from the city mains line is measured by the meter at the entrance to the heat station. The solar energy system and the hot water supply are made through the directories provided after the water meter. Since the total amount of water entering is obvious, no additional measurements are required for hot water consumption. The hot water coming from the solar energy system and the heat exchanger is controlled and directed to the places of use. Depending on the temperature of the water used, the guidelines for hot water supply vary. If the requested water temperature is lower than the temperature of the solar energy line, the supply is made via this line. If sufficient temperature is not achieved in the solar energy system, the floor station continues its normal operation. However, it is possible to perform temperature compensation on both lines with the additional three-way valve control. For this purpose, the water coming from both lines is mixed and sent to the places of use.

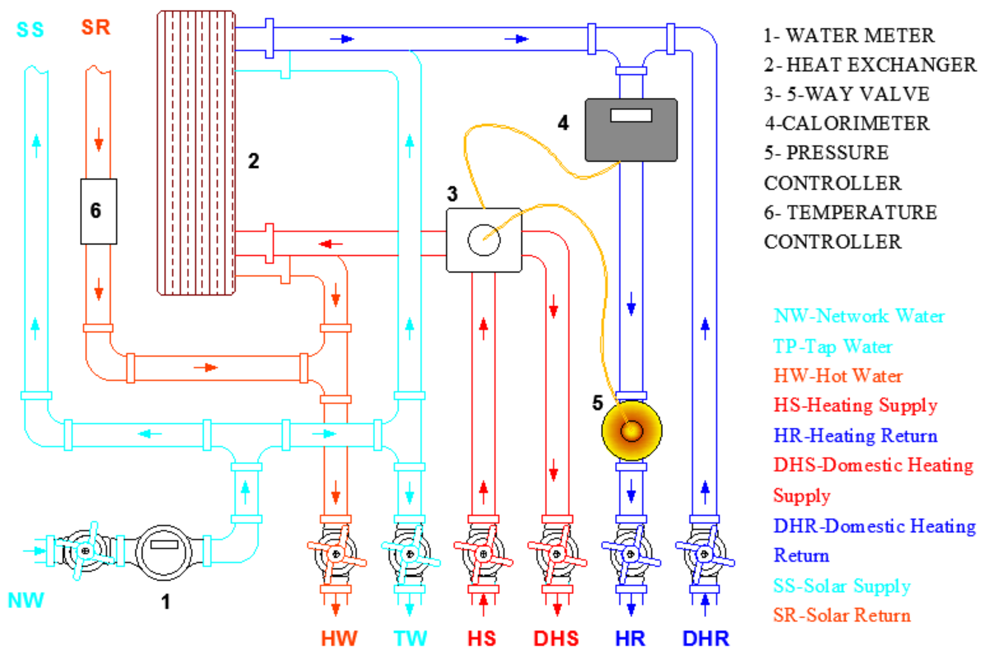

Figure 1. Schematic view of heat substation supported by solar energy system

Heat substations always operate primarily with utility water. That is, the heating of the stand-alone unit is stopped when the working water is supplied. The solar energy system also has a priority when the utility water is supplied. There is no need to stop the heating process if there is enough water at the temperature. Thus, the cooling of the stand-alone unit is prevented during long-term use. In addition, the energy provided by the solar power line is not included in the total energy consumed, thus providing additional savings.

Domestic hot water use is quite variable according to the apartment flats. The main factors such as the use situation of the building, the geographical conditions, the time of year and the usage habits of the household determine hot water consumption. However, it is clear that everything will vary according to the lifestyle of the user.

2.1. Theory/calculation

Although heat exchanger types are available in a wide variety of types and sizes, they are often used in plate heat exchangers in heat exchangers. The main reasons for the preference of the plate heat exchangers are that they are smaller in size for the same capacities and have a higher total heat transfer coefficient. For this heat exchanger, which works according to the principle of sudden water heating, external insulation is made and the energy losses that occur in this way are ignored. The enthalpy of the water carried in the plate heat exchangers evaluated according to the principle of continuous operation is considerably larger than the kinetic and potential energies. For this reason, these values are not considered in calculations.

Heat transfer in the heat exchanger is assumed to be between only two fluids. If there is no good insulation, the heat loss to the surrounding area must also be taken into account. It is also assumed that there are no phase changes. In this case, the first law of thermodynamics can be written in terms of heat transition from enthalpy equilibrium [11, 12];

$$m_h\left(h_{h,in} - h_{h,out}\right) = m_c\left(h_{c,out} - h_{c,in}\right) \tag{1}$$

$$\dot{m}_h c_{ph}\left(T_{h,in} - T_{h,out}\right) = \dot{m}_{ch} c_{pc}\left(T_{c,out} - T_{c,in}\right) \tag{2}$$

In this expression, the left side of the equation represents the heat loss from the hot side, and the right side represents the heat that the cold fluid acquires. Here, h, m, c_p, T_1 and T_2 represent enthalpy, mass flow rate, specific heat, inlet and outlet temperatures, respectively, of the fluid. The $_{in}$ and $_{out}$ subscripts used indicate the values of the hot and cold flow, respectively, and the in and out values indicate the inlet and outlet values.

Heat transfer in the heat exchanger is through conduction and convection. In this case, the heat transfer rate must be defined. This expression can be calculated as follows;

$$\dot{Q} = UA\Delta T_{lm} F \tag{3}$$

Where U is the overall heat transfer coefficient, A is the heat transfer cross-sectional area, F is the correction factor. ΔT_{lm} is the mean logarithmic temperature difference and can be calculated from equation .

$$\Delta T_{lm} = \frac{\Delta T_2 - \Delta T_1}{\ln \frac{\Delta T_2}{\Delta T_1}} \tag{4}$$

The average hot water consumption for a standard three-room apartment and a family of four for circular use is set at 160 liters. Hot water production systems with solar energy work; solar radiation, radiation collector surface area, efficiency of the system and installation are considered [13]. Monthly solar radiation values in Turkey are given in Table 1 [14]. The collector efficiency varies depending on the characteristics of the heating systems used.

Table 1. Monthly solar radiation and sunshine duration values

Months	Sunshine duration	Total solar energy	
	(hour/month)	kWh/m^2-ay	kcal/m^2-gün
January	103,00	51,75	1483,23
February	115,00	63,27	1813,41
March	165,00	96,65	2770,12
April	197,00	122,23	3503,28
May	273,00	153,86	4409,84
June	325,00	168,75	4836,61
July	365,00	175,38	5026,64
August	343,00	158,40	4539,97
September	280,00	123,28	3533,38
October	214,00	89,90	2576,66
November	157,00	60,82	1743,19
December	103,00	46,87	1343,36
Total	2640,00	1311,16	37579,68
Average	220	109,26	3131,64

The increase in the difference between the outside air temperature and the collector surface temperature decreases the collector efficiency. The complexity and length of the installation can lead to reduced efficiency, as well as reduced efficiency with forced circulation. The energy gained from the solar energy system can be calculated as follows:

$$Heat\ (produced) = solar\ radiation * efficiency\ of\ solar\ panel * efficiency\ of\ plumbing \tag{5}$$

The calculations for the panel yields were based on yield values of 70% for the mean value and 75% for the installation yield [15]. However, for non-standard or precise calculations, these values must be specified separately.

The daily amount of hot water required can be calculated as follows;

$$Q_{water} = m_{water} c_p (T_{water} - T_{network\ water}), [kj] \tag{6}$$

The total heat energy generated is found by multiplying the generated heat by the collector surface area. The increase in the water temperature can be evaluated as a sign of the energy gain of the system.

3. Results

In central heating systems, water circulation is provided with the installation water, which is generally 90ºC output temperature. However, it is natural that there are different temperatures at the entrances of independent units of the building and radiators. These temperature differences significantly affect the energy consumption of the units. The total heat energy distribution provided by the central heating systems operated on the basis of the outside air temperatures is given in Table 2 [7]. The difference between the installation and return temperatures is an important indicator of the heat delivered to the units when losses are ignored. The heat energy to be supplied for the domestic water supplied from the heating system must be determined taking these values into consideration.

Table 2. Domestic installation values based on outdoor temperatures

Outdoor tem., ºC	Domestic heating supply temp., ºC	Domestic heating supply temp., ºC	Temperature difference, ΔT	Flow rate, kg/s	Total heat energy, W
−30	74,09	32,05	42,04	0,0621	10985,76
−25	70,17	31,12	39,05	0,0602	9892,21
−20	66,25	30,14	36,11	0,058	8815,25
−15	62,25	29,14	33,11	0,0555	7734,48
−10	58,22	28,09	30,13	0,0525	6659,48
−5	54,14	26,98	27,16	0,0489	5591,40
0	50,03	25,81	24,22	0,0443	4517,10
5	46,83	24,32	22,51	0,0364	3449,52
10	45,53	22,51	23,02	0,0245	2374,40
15	44,1	21,23	22,87	0,0137	1319,07

The primary heat source for heat stations is the central heat substation or source. For utility hot water, the capacity of these systems needs to be accounted for or re-evaluated for older systems. This additional energy requirement is met considerably in the solar power system supported floor stations. No changes are needed, depending on the enhancements made for many systems.

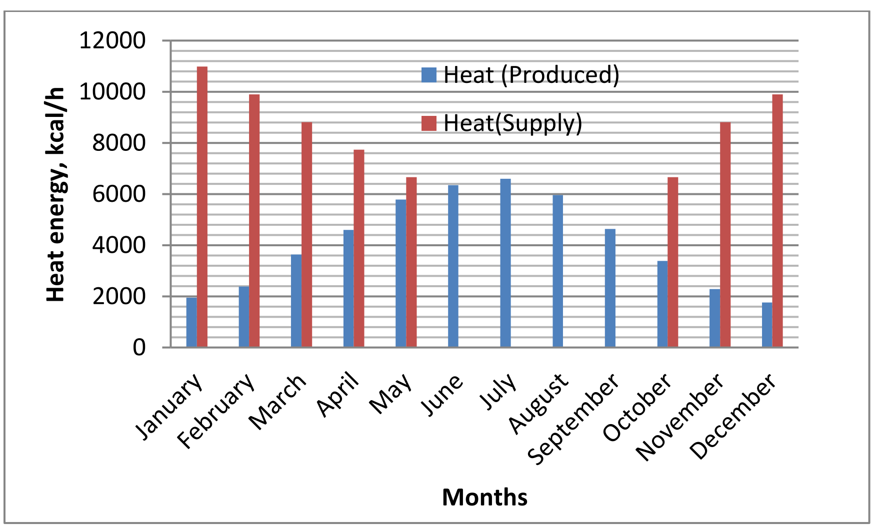

Figure2. Central heat generation and solar energy gains

The energy values given in Table 2 and the additional heat energy produced and provided according to the calculations made according to Equation 5 were compared. These values are shown in figure. In summer conditions, full heating water supply is provided with no heating required for increased heat supply and heating.

4. Discussion

Standard type systems are considered in determining the energy provided by solar energy collectors. Turkey's solar energy potential is evaluated monthly and included in the calculations taking into account the average monthly temperature values [16].

Table 3. Monthly average temperature values

Months	January	February	March	April	May	June
Temp., ºC	3	4	7	11	16	22
Months	July	August	September	October	November	December
Temp., ºC	29	28	22	15	8	4

Storage of hot water produced in heat stations is possible. However, they are often not preferred because they occupy too much space when placed in the entrances of the flats. It is also evident that it will provide extra load to the heating system with continuous hot water addition. Since the solar hot water system is always ready for hot water, this problem comes to an extreme.

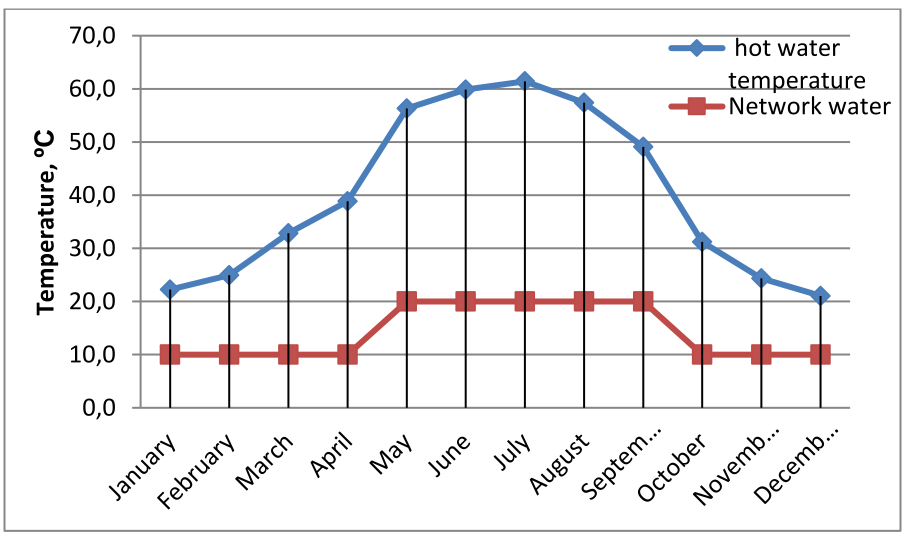

Figure 3. Average hot water temperature values

Figure 3 shows the mean values of the average water temperature that can be obtained according to the calculations made with the low collector and installation efficiency and the average solar energy potential of Turkey. The mains water temperature is taken as 10 and 20ºC respectively in winter and summer conditions. Considering these calculated values, it can be argued that the use of hot water from the solar power system is beneficial for 8 months (over 30 ° C) of the year.

The biggest problem when producing hot water with solar energy is the inadequate heat production in closed and cold weather. This problem will continue for systems that are combined with heat floor stations. The main thing here is to provide single-center control of heating systems as well as to ensure efficient use of the system under appropriate conditions and to provide more comfort in heating.

Conclusions

In the heat substations, the working water can be supplied at 20-70ºC temperature range with hydraulic and thermal control systems. With the inclusion of the solar energy system it is easy and economical to supply water at the desired temperature irrespective of the water used. The energy from the central heat source and the solar energy system can be assessed together in accordance with their use requirements. Energy savings can be achieved through the provision of solar energy system priority. In addition to the hot water production at the hot water stations, hot water is available in the solar energy system so that it can be used without any waiting time. If heavy winter conditions do not participate in the account, hot water, which can be above 20ºC throughout the year, can be evaluated for many hot water applications.

It is possible to keep the temperature of each section in the independent unit different from each other. As hot water is used primarily, there is interruption in heating unless additional measures are taken. When it is thought that hot water is available even with daylight, it is predicted that these intercepts will decrease significantly in favorable weather conditions. In the summer months, the use of hot water will continue comfortably and economically without the need for additional heaters as a result of shutting down the heating system. It will be appropriate to evaluate the utilization and operational efficiency of these systems, which are provided with a single-centered control and compact structure of the heat and water systems. Evaluation of appropriate use according to region and building characteristics is also a research topic.

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