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Economical investigation of an integrated boiler–solar energy saving system in Jordan

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ABSTRACT

Jordan is relatively poor in conventional energy resources and is basically a non-oil producing country, i.e. its energy supply relies to a very large extent on imports. It is therefore unlikely that any future energy scenario for Jordan will not include a significant proportion of its energy to come from renewable sources such as solar energy. The lack of an integrated energy saving system which utilizes the solar energy for domestic hot water as well as for building space heating was the main motivation for the present study. In Jordan, there is no existing system can provide the integration mechanisms of solar energy and fuel combustion with electrical ones. Also adding new and related products increases sales of current boilers products and can be offered at competitive prices.

During our investigations, it has been found that the market demand for boiler–solar integration system in terms of the system acceptability, system feasibility, and system values is very high especially after the increased in oil prices during the last 3 years, i.e. 2006–2008. The market trend shows that even though solar collector is not attractive as an energy source for domestic hot water, but the combined system for space heating and domestic hot water is fully accepted. However, the market demand for such a system is not completely identified yet but the awareness and the discussion of the idea shows a good potential.

The economical study about the integration system of boiler and solar energy shows that using solar water heaters to heat space and for domestic water is cost-effective. Payback can be as low as 3 years, and utility bills are much lower than they would be using a conventional heating system. The initial draft and design of a prototype for the boiler–solar–electrical integration system has been carried out.

1. Introduction

One of the most important energy sources in our economy is still oil, which is not renewable considering our lifetime. Jordan is an energy importing country; about 96% of its energy needs supplied from abroad as crude oil and refined products. Hrayshat and Al-Soud [1] pointed out that the share of solar energy in the total energy mix in Jordan is estimated to be around 1.7% during the year 2002. They also showed that the expected share of solar energy in the total energy mix in the year 2007 is estimated to be around 2.1%. During the Renewable Energy International Conference which was held in Bonn, Germany during 1–4 June 2004, Jordanian authority has been committed to have 5% of its total energy requirements from renewable energy resources for the next coming 5 years, e.g. Al-Salaymeh [2]. The Jordanian authority and especially the ministry of Energy are working currently to have 7% of the total energy requirements in Jordan to be from renewable energy resources in 2015 and 10% in 2020. The share of renewable energy in the primary energy supply of the southern Mediterranean countries has been relatively low and varies from a minimum of 0.6% in Tunisia to a maximum of 19% in Palestine. This share can reach 2.0% in Algeria, 2.8% in Lebanon, 4.4% in Egypt, and 6.5% in Syria.

In fact, Jordan is blessed with huge amounts of renewable energy resources, particularly solar energy. In order to reduce dependence on the imported oil, Jordan has pursued programs for promoting solar energy involving systematic monitoring and assessment of technological developments combined with the implementation of appropriate technologies, demonstrations and pilot projects [3–7]. The current tendency in Jordan is to use in future various solar energy applications in the over all mix of energy in Jordan, as well as identifying potential areas for utilizing future technologies and recommending future courses of action to encourage the commercial utilization of solar energy technologies.

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As we know, all sources of energy may be grouped into two general categories; income energy, which is the energy reaching the earth from outer space such as solar energy, and capital energy, which is the energy that already exists on or within the earth such as fossil fuels, e.g. [8]. The hot Sun gives light and life and it is an inexhaustible supply of pollution-free power. The ancient Egyptian Pharaohs solar heated their palaces by capturing solar energy in black pools of water by day and draining the hot water into pipes in the floor of the palaces at night. Affluent ancient Greeks designed their homes orientated to the sun to use winter sunlight for heating. Large south-facing windows were used to collect solar heat, which was stored in massive walls and floors for gradual release throughout the night. Solar energy put to full use would help to give the world energy independence, minimizing dangerous pollution levels and our dependence on fossil fuels. Therefore, solar energy can be considered as the most abundant continuing source of energy available to the human race.

One of the promising usages of renewable energy technology is the installation of the solar collector system, which has already demonstrated its effectiveness and holds great promise for hot water generation. The applications of the solar collector system have become more widespread in both developed and developing countries [9,10]. Due to high and reliable solar irradiance of about 5.5 kW h/m^2 day a domestic usage for solar energy in Jordan over the life time has the potential to produce a domestic hot water in addition to the heating and cooling of buildings for about 330 sunny days per year using solar collectors [11]. Solar irradiance varies with season and time of the day due to the various Sun positions under the unpredictable weather conditions [12]. Conventionally, different mathematical models have been developed in Europe to predict the solar irradiance on various inclined-surfaces using horizontal data [13,14]. Data on average hours of sunshine or average percentage of possible sunshine hours are widely available from stations in many countries, e.g. [15]. Al-Salaymeh [2] developed a mathematical model for the prediction of global daily solar radiation on horizontal surfaces for Amman city in Jordan.

2. Aim of the work

The price of oil is increasing and the energy bill is very expensive for Jordan. As it is known, Jordan is imported oil from neighboring countries and this oil costs too much. Currently, a local study on renewable energy reported that solar technologies are potentially suitable for wide scale applications in Jordan. These results show that Jordan need to begin to rely more on solar energy in order to reduce the dependence on imported expensive sources of energy. The energy demand, in Jordan, was doubled during the last 20 years, and expected to continue at the same rate. Hence, all recent energy forecast scenarios showed that the national consumption might double between 2015 and 2020. Due to increasing oil prices, the financial aspect of this problem has increased and its resultant outcomes are clearly observable these days in Jordan.

Utilizing of solar energy with boiler systems for domestic hot water as well as for building space heating can save energy and therefore can reduce the energy cost for domestic uses. The idea shows that a significant market segment is willing to invest in this system mainly to the expected increase in the fuel cost. The market trend shows that even though solar collector is not attractive as an energy source for domestic hot water, the idea of the integration is fully accepted and it needs to be tested on real cases.

The present investigation aims to develop a new energy saving system that integrates solar, boiler, and electrical systems for heating purposes. The draft of the initial features and characteristics of the system is shown in Fig. 1. The system pilot testing includes offering the idea of the system to a sample group of customers to determine if these customers need the system and are willing to buy it, identifying if there is a demand for the new system, whether modifications or changes to the terms and conditions will make the system more appealing, and what features or processes need adjustment, and calculating the cost and price of the system. The proposed methodology based on the economical study about the integration system of boiler and solar energy.

3. Theoretical background

Energy is one of the most important factors in wealth generation, economic growth and social developments of the present countries. Based on historical data, one can observe that there is a strong relationship between the development of economic activities and availability of energy resources, i.e. energy is of vital importance all over the world for the process of production and manufacturing, and as such, a key element of sustainable development of countries.

Referring to the measurements on radiation as well as to the variation in the topography and climatology of Jordan, the country is divided into five regions [16–18].

1. The southern region (29–30.5 °N, 35–38 °E): in this region, the annual daily average values of global irradiance are between 6 and 7 kW h/m^2 day.
2. The eastern region (30.5–32.5 °N, 36.5–39 °E): in this region, the annual daily average values for global of about 5.0 kW h/m^2.
3. The middle region (30.5–32 °N, 35.5–36.5 °E): in this region, the global irradiance is about 4.5 kW h/m^2 day in this region.
4. The northern region (32–33 °N, 35.5–36.5 °E): in this region the annual daily average value of global irradiance is about 5.5 kW h/m^2 day.
5. The western region (30.5–33 °N, 35–35.5 °E): in this region, the annual daily average values of global irradiance are between 4.5 and 5 kW h/m^2 day.

In general, the abundance of solar energy in Jordan is evident from the annual daily average of global solar irradiance, which ranges between 5 and 7 kW h/m^2 day on horizontal surfaces. This corresponds to a total annual value of 1600–2300 kW h/m^2 year. The measurements data that including horizontal solar irradiance and sunshine duration of solar irradiance for Amman city (latitude of 32°1′N) has been taken. Al-Salaymeh [2] predicated global solar radiation data on a horizontal surface for Amman city as shown in Fig. 2. The scatter in the data shown in Fig. 2 is due to low number of years that is used in the calculation (only 3 years).

Different correlation formulas for global solar radiation for Amman city that used the Sine wave correlation formula with constant Y-value, Lorentzian correlation formula, Gaussian correlation formula and the 4th order polynomial degree are shown also in Fig. 2, e.g. Al-Salaymeh [2]. The mean value of energy of quasiglobal radiation for Amman equals 5324 kW h/m^2 day. Jordan receives the most solar energy in June (mean value 7995 kW h/m^2) and the least in December (mean value 2676 kW h/m^2).

Fig. 3 shows the meteorological data for sunshine duration in Amman which acquired from observed mean values on meteorological stations for 3 years. The scattering in the data is very high because the number of years used to calculate the average sunshine duration is only 3 years. The maximum value of sunshine duration in Amman occurs in June and July (mean value is 11.86 h for June and 12.05 h for July) and the least in December (mean value 5.14 h), e.g. Al-Salaymeh (2006).