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Study of Sunlight Heat Effect on Coupled Air Handling in Air Conditioning System and Energy Consumption of Building in Tehran City

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Abstract: Air conditioning systems are definitely necessary and vital components in modern construction and it is not possible to keep heating balance and quality of indoor air of high-rise buildings and rooms with particular application such as server rooms without such systems. The importance of this issue caused association of major part of energy consumption in buildings to their air conditioning systems hence, it is required to focus on frugality methods in energy consumption. This study aimed on presenting an analysis of effect of radiation energy on air transfer channels in buildings consisting central air conditioning system in order to use obtained results and reduce heating energy consumption. Climate features of Tehran urban region have been considered as background presumption to make this study more practical.

Key words: Central air conditioning system, sun radiation, air transfer channel, heating process, Tehran

INTRODUCTION

HVAC stands for a set of technologies associated with heating, ventilation and air conditioning that consist of relevant technologies to comfort creation through air conditioning and proper temperature conditions for indoor environments. Design of HVAC systems is one of main sub-disciplineof mechanical installations engineering formed based on principles of thermodynamic, fluid mechanics and heat transfer. Refrigeration is sometimes added to this abbreviation changing it to HVAC and R or HVACR or ventilating is dropped in some cases making it HACR. HVAC plays an important role in design of medium to large office and industrial buildings such as skyscrapers and aquatic environments such as aquariums so that environmental safety and health depends on humidity and temperature changes.

Devices related to HVAC systems were invented at the beginning period of industrial revolution benefiting from new methods of modernization, accessing to higher productivity and creating control systems by different companies and inventors all around the world (Swenson, 1995). The relation between three functions of heating, ventilation and air conditioning provided thermal comfort in buildings, acceptable indoor air quality and propercosts related to installation, operation and maintenance. These systems can provide ventilation, reduce air infiltration and maintain pressure relationships between spaces (Anonymous, 2012). The means of air delivery and removal from spaces is known as “Environmental Air Distribution System”. There is a considerable financial turnover in HVAC industry through creating job opportunities for installation, repairing, maintenance, design and construction, manufacturing and selling components, education and researches (Kodmany, 2013).

In past, heating, cooling and air conditioning systems installed in buildings separately without considering the interaction between them and necessityof foreground for insulation and air leakage. Central heating system (radiator) used in cold climates as thermal system in private houses and public buildings. Such systems consisted of a boiler, furnaces (torch) or heat pump to warm water, steam or air so that all of these devices are located in a central place such as powerhouse or installation room in large buildings. Cooling systems are generally in form of evaporative or gaseous coolers and penetrations and windows were applied when indoor air conditioning was required. Now a days, standard industrial packages (Fig. 1) are used in large buildings in which ventilation system and central heating are required (Bearg, 1993) and these systems are located in installation room on the roof or adjacent to the buildings. Locating position and capacity of package is related to conditions and needs of building determined by mechanical installations engineer. Different parts of a packaged air conditioner can be seen. These systems are

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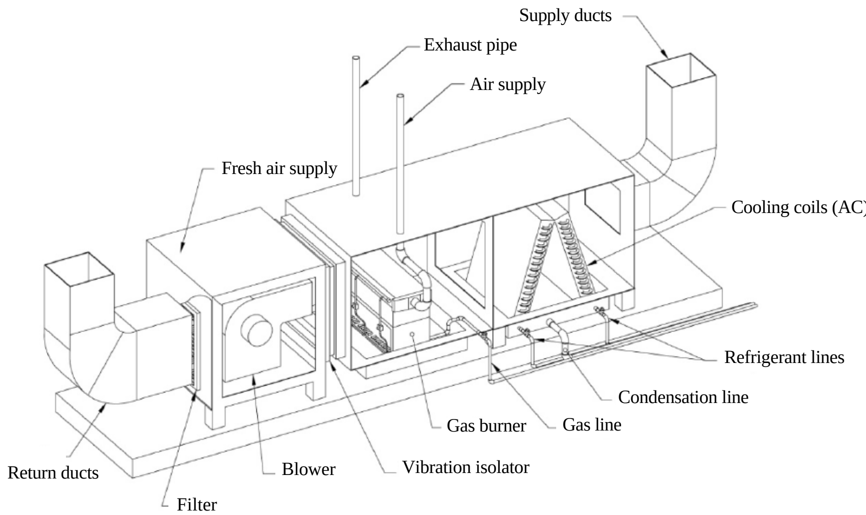

Fig. 1: Schema of apackaged air conditioner

similar to a central part attached to a network of air channels made of galvanized iron also have anexhaust system that absorbs the compressed outdoor air and regulates its pressure and heat based on required standard for indoor air temperature using installed components in package. In some cases, this device can remove air pollutions and pomp the usable air into air channels. These packages generally have high-energy consumption due to their compressed heating and cooling systems.

Previous studies: Paying attention to the issue of reducing energy consumption in air conditioning systems has been considered by researchers (Rezaie and Rosen, 2011) and some solutions including air leakage insulation in different parts of building and insulation of air transfer channels together with possibility of use of non-centralized heating-cooling system have been recommended. The same issue has been discussed in (Werner, 2006) considering cultural and climate conditions in Europe. Georgia (2005) has emphasized on insulation and preventing form air leakage as well as its effect on reducing energy consumption. Research (Bell, 2011) consists of an interesting subject about room air change rate during the year and necessity of reducing energy consumption through adjusting temperature regulation diagram through central ventilation system with regulated temperature diagram by the person. In other words, they concluded that HVAC system would change (increase or decrease) the temperature more than optimal level in accordance with optimal temperature regulation by person. Study of Kodmany (2013) has addressed the issue of high-level absorption of sun radiation energy by tall buildings and its effect on increased cooling energy consumption.

Above all, studies Holm (2012) and Pauschinger (2012) have addressed use of solar heating energy in these systems. Use of solar energy is possible through converting it into electrical energy while this issue is not directly related to HVAC system but the important point is extractable level of sunlight energy and energy storage methods in different seasons of Germany and Denmark. Thermal energy storage is possible heating specific fluids storing them in insulated tanks however this process required high costs. In this regard, this process is not usable for HVAC system. In conclusion, it can be found that the issue of direct use of solar energy in air conditioning system has not been addresses and previous researches have been more on optimization of engineering design of these systems and other issue such as insulation and thermal energy storage.

MATERIALS AND METHODS

Present theory: This studied aimed on use solar radiation energy in order to reduce heating energy in HVAC packages considering radiation condition in Tehran City, Iran. The energy of sun is one of major energy sources in solar system. About 4/2 million tons of mass of the sun is converted to energy per second. Accordingly, this luminous star can be considered as a huge energy source for up to 5 billion years ahead. Central temperature of the sun is about 10-14 million degree of centigrade that electromagnetic waves emits from its level with a temperature about 5600°. The sun is source of different forms of energies known so far in earth including stored fossil fuels in earth, wind energies, waterfalls, sea waves, etc.

Similar to other energies, solar energy can directly or indirectly convert into other forms of energy such as heat, electricity, etc. while some barriers including scientific and technical shortcoming in conversion have led to low-level use of this energy due to lack of knowledge and field experience, (variety of energy amounts because of climate and seasonal changes) and broad range of distribution. Iran is located in districts with high radiation and studies show that application of solar facilities in Iran is feasible. Hence, these facilities can provide a part of required energy in Iran.

However, solar radiation energy (based on lx) can be calculated based on day, year and other parameters through following Eq. 1:

$$E = 128\times10^{3}\left(1+0.033412\cos(2\pi\frac{Dn-3}{365})\right)e^{-cm}IX$$

Where:

Dn = The day number of year
c = Coefficient of light dispersion in atmosphere
m = Mass light reflection by clouds

The last two factors change within a year or even a day but they are recorded for each region by relevant organizations. These factors are empirically predictable. Conversion of radiation intensity to unit of power (Watt) is done through a constant coefficient of light radiation (r) ad when this coefficient is equal to 1; all electromagnetic radiation energy of sunlight is adsorbed at by level.

According to the experts in this field, Iran has a high potential in terms of solar energy because of having 300 sunny days in more than its 2/3 and average radiation of 4/5-5/5 kWh/m^2 per day (Matthias, 2005).

As it was mentioned, the aim of this study is examining possibility of using this heating energy in air conditioning system. Entrance part of air conditioning systems channels consists of an air exhaust fan installed in the entrance of a channel that absorbs outdoor air into the system. Entrance path of air channel is usually short so that its space under the outdoor radiation is not considered. The assumption is that this fluid is passing through a channel with volume of V, space under radiation of S with pressure of P in an air conditioning system before air enters into the package. Channel is made of galvanized steel determined by heat transfer coefficient (α) and light radiation coefficient (r). Galvanized sheet consists of different layers placed on a ferrous layer and the outside layer is made of zinc. In accordance with measurements it is assumed that galvanized sheet receivesonly average 170 w/s of heating energy from solar radiation with reflection equal to r = 0/7; hence, it can be stated with a good approximation that heat distribution is uniform at sheet level and only its depth distribution changes. According to the equation of heat distribution in a three spatial object (Farlow, 1982) (Fig. 2):

$$\frac{\partial u}{\partial t}-\alpha\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)=Q$$

Where:

α = Thermal diffusion coefficient of galvanized sheet
u = Temperature (thermal kinetic energy distribution) that is energy derivative with respect to time equal to the thermal power entered into the system or Q

This equation indicates that heat transfer rate, given the constant thermal energy source, has a transient state and after a short time all absorbed heat by galvanized sheettransfers to its internal side while the temperature of sheet in constant. Following equation consists of T (thermal level), Z (sheet thickness), Q (entered thermal power), K (constant coefficient) obtained from the above partial differential equation, α (thermal diffusion coefficient):

$$T_{in}=\frac{QZ}{Kat}+T_{out}$$

With increase in t (time), fractional sentence, that indicates adsorbed thermal power by sheet will be zero and the internal and external temperature of sheet will be equal; at this state, total adsorbed heat will transfer into the air transfer channel. The required time to reach this state depends on heat transfer coefficient that is low in insulator materials and this leads to a long time for thermal saturation of insulator.

According to the mentioned points, total absorbed thermal energy transfers to the fluid inside of channel after a short time. Given the constant air pressure of fluid inside of channel we consider now thermodynamic equations of thermal capacity at constant pressure while it is required to consider general thermodynamic equations in order to determine thermal capacity of compressed air. For this purpose, we have:

$$\Delta T = PV$$

Where:

T = Temperature
P = Pressure
V = Fluid volume

Given the constant internal volume of channel, increase pressure by air exhaust pomp would lead to a proper increased level in temperature. The conducted experiments indicated that in a normal HVAC system, temperature of a compressed sucked with 2 atmosphere pressure in a normal summer day will be equal to 60°C. In

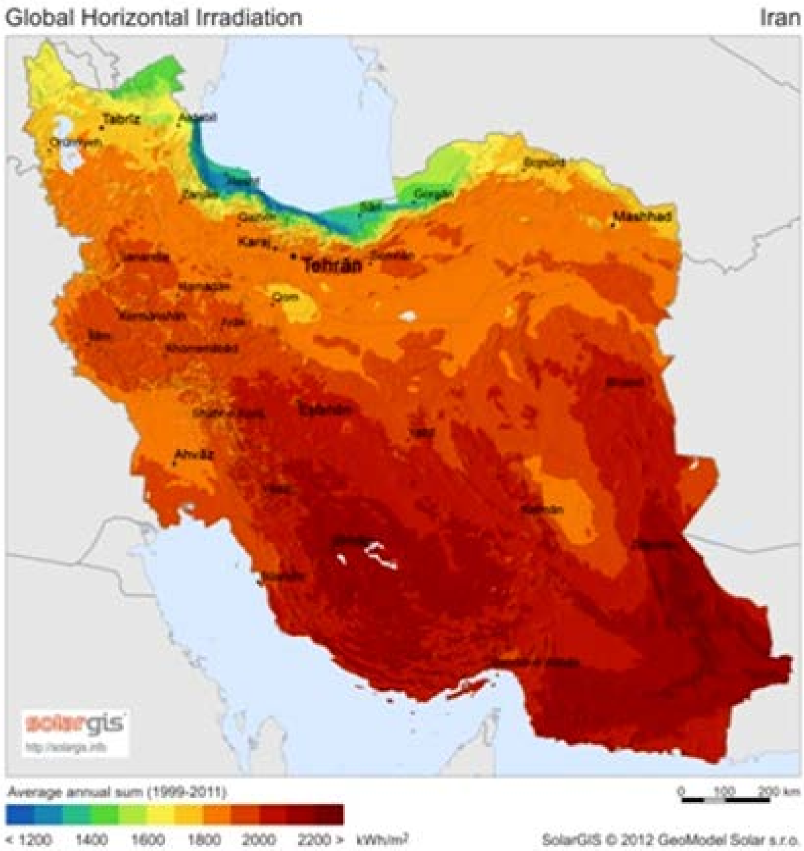

Fig. 2: Tehran is located at a range with average radiation >2000 kWh/m^2 at horizontal level

such conditions, thermal capacity of air will be equal to Cp = 1009 J kgK^{-1}. According to constant pressure thermodynamic equations will have:

$$C_p = 1009 = \frac{\partial Q}{\partial T} + P\frac{\partial V}{\partial T}$$

That Volume (V) and input heat to system Q are constant based on the conditions of addressed problem. Then will have:

$$\Delta T = \frac{Q + PV}{C_p}$$

RESULTS AND DISCUSSION

According toparametric numbers inserted into equation above with mentioned amounts and transient air volume equal to 0/5 m^3 through the 1 m^2 space of channel level, it is resulted that a normal galvanized sheet with optical reflection coefficient (0/7) can increase the transient 2 atmospheric air temperature by 1°C during a normal summer day. Now, if we reduce the reflection coefficient of galvanized sheet level by 0/1 limning it, an increase up to 3° might happen for transmitted air temperature. Moreover, it is possible to increase the ratio of light absorbing surface to transient air volume up to three times more through changing the shape of air transmission channels without any change in flux return of channel. In this case, thermal level will be increased. Experiments indicate that in a wintery day of Tehran with free air temperature to 0°C and compressed air inside of channel about 20°, temperature of transferred air can be increased by 10-15°C selecting appropriate diagram and path that is able to present the maximum light-absorbing surface per minimum transferred air together with minimum coefficient of radiation reflection. Measuring the consumed energy in thermal part of a HVAZ package, indicated that it is possible to reduce thermal energy consumption up to 20% in a normal winter day at the time interval of sunlight absorption. In general the return on this method depends on space of radiation, surface radiation coefficient of channel and pressure of transferred air and it seems that an optimal design can

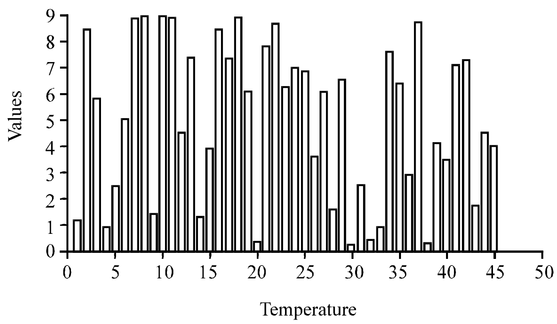

Fig. 3: Reduced energy consumption rate in a studied heating system

increasingly reduce energy consumption of a HVAC system. Figure 3 shows the level of recorded frugality based on fix shape of channel (the volume of transferred air per m^2 from radiation absorbing level is equal to 0/2 m^3 and irradiated space is 10 m^2 and radiation rate 0/1) during first 45 days of Autumn, 2016. The effective and unpredictable factors during this period include cloudy sky and temperature of outdoor air. Exhaust system of air would regulate the air pressure about 2 atmosphere.

It might be imagined that application of this phenomenon is only useful for the part of ventilation system that prepares the required air for heating system and it is used in cold weather while the channels consisting of outgoing air from ventilation system can be exposure to sunlight in this state, the heated air moves rapidly toward exit ramp and the power consumption in exist fans can be saved during all seasons. According to the measurements of ventilation outlet channel, the energy consumption in exhaust fans can be saved up to 30% during hot days of year.

CONCLUSSION

This research was conducted to present a solution for using natural sun radiation and effect of heath absorption in air channels in order to reduce energy consumption by these systems.

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