An Overview on Ground Source Heat Pump System

D.B. Jani[1*], Tailor Ravi[2], Solanki Mayur[3], Chauhan Sanjay[4], Tandel Vishal[5], Vania Pratik[6]
[1,2,3,4,5,6]*Mechanical Department, GEC, Dahod, Gujarat Technological University, Ahmedabad, India*
[*]*Corresponding author*

***Abstract*— Ground source heat pump systems offer economical alternatives of providing thermal comfort for use in various industrial, commercial and residential air conditioning applications. As the cost of energy continues to rise, it becomes imperative to save energy and improve overall energy efficiency by searching renewable sources of energy. In this light, the ground source heat pump becomes a key component in an air conditioning system with great potential for energy saving by use of renewable energy available from beneath the earth surface. Improving ground source heat pump performance, reliability, and its environmental impact has been an ongoing concern. Recent progresses in ground source heat pump systems have centered upon advanced cycle designs for both heat- and work-actuated systems, improved cycle components (including choice of working fluid), and exploiting utilization in a wider range of applications in different climatic conditions. For the ground source heat pump to be an economical in operation continuous efforts need to be devoted to improving its performance and reliability.**

***Keywords*—Ground source heat pump, geothermal energy, air conditioning, Energy efficiency.**

I. INTRODUCTION

The ground source heat pump (GSHP) has evolved to become a mature air cooling technology over the past two decades. However, it is not applied as widely as it should or could be. Initial costs, system design and integration remain to be challenging problems, since few major vendors of refrigeration systems offer large-scale heat pumps. Efficient use of geothermal energy in such energy-intensive operations as district cooling/ heating and drying is crucial to the reduction of net energy consumption and hence emissions of greenhouse gases. With the eventual acceptance of a carbon/energy tax around the world energy, energy conservation will become a key concern in many industrial operations. With raising cost of fuel and global warming at the forefront of world attention, the interest in ground source heat pump as a means of geothermal energy use (Fig. 1) appears to have been resurrected. Geothermal heat pumps offer one of the most practicable solutions to the greenhouse effect by use of geothermal renewable heat or cold energy. It is the only known process that recirculates earth geothermal heat or cold back into a heating or cooling air conditioning process; offering energy efficient and environmentally friendly heating and cooling in applications ranging from domestic and commercial buildings. Practical studies have shown the potential of heat pumps to drastically reduce greenhouse gases, in particular CO_2 emissions, in space heating or cooling applications. The positive impact on environment depends on the type of heat pump and the energy-mix and efficiency of driving power used [1-3].

Ground source heat pump is a highly efficient, renewable energy technology for space heating and cooling. This technology relies on the fact that, at depth, the Earth has a relatively constant temperature, warmer than the air in winter and cooler than the air in summer. A GSHP can transfer heat stored in the Earth into a building during the winter, and transfer heat out of the building during the summer. GSHP technology is receiving increasing interest because of their potential to reduce primary energy consumption and thus reduce emissions of greenhouse gases [4].

Geothermal energy of the earth is used (Fig. 2) in three main ways: electricity generation, direct heating, and indirect heating and cooling via geothermal heat pumps. These three processes use high, medium, and low temperature resources, respectively. High and medium temperature resources are usually the product of thermal flows produced by the molten core of the earth, which collects in areas of water or rock beneath the earth surface. Low temperature resources are near ambient temperature and are mostly attributable to the solar energy incident on the ground and ambient air. High and medium temperature thermal resources are often deep within the earth, and the depth affects whether they can be exploited economically as drilling and other extraction costs can become comparatively greater at deep surface below earth. Low temperature geothermal resources are abundant and can be extracted and utilized in most locations around the world. Extracting such thermal energy is relatively simple because the depths involved are normally small. Heat pumps extract low temperature thermal energy and raise the temperature to that required for air conditioning of residential and commercial buildings. Geothermal heat pumps can provide an environmentally and economically viable advantageous option for space heating, and can also be utilized for space cooling. In this article, we review geothermal heat pump systems and recent developments and compare them with other heating options, with the objective of improving understanding of geothermal heat pump systems and increasing their utilization in appropriate applications. GSHP systems have become attractive choices for both residential and commercial buildings because of their higher energy efficiency compared with conventional air source heat pump (ASHP) systems [5-7].

II. WORKING OF GSHP

Heating and cooling needs increase total global energy requirements and impact natural resource use. Residential buildings account for approximately 21% of total energy consumption in developed countries, and for developing countries, around 32%. Heating and cooling energy use in buildings (both commercial and residential buildings) through 2016–2018 in different regions are shown in Table 1.

TABLE I. Comparison between commercial and residential energy usage by Year 2016-18.

Country	Total energy consumption (PJ)	Residential energy consumption (PJ)	The percentage of residential energy consumption to total energy consumption (%)	CO_2 emissions (Mt of CO_2)
India	23960	7449	31.1	2077
Japan	12311	1853	15.1	1147
Canada	8013	1345	16.8	541
USA	63431	10315	16	4833
Germany	9375	2342	25	732
Turkey	4096	867	21.2	339

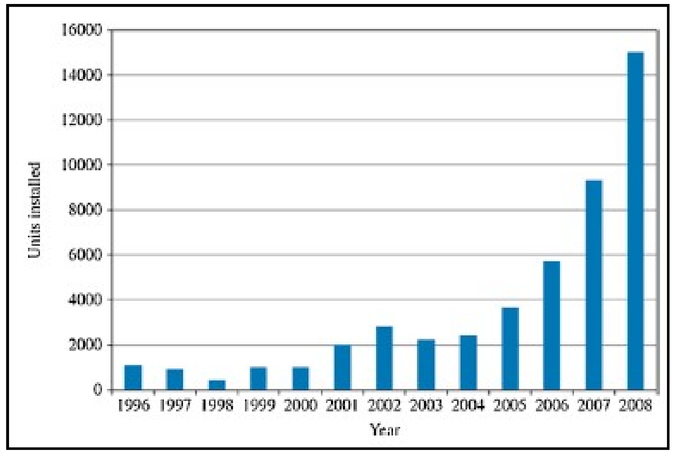

Fig. 1. Progressive development in utilization for geothermal energy

Fig. 3 depicts that when geothermal energy is employed in a HVAC system, there is a potential of reducing the energy bill by half. Space heating has the greatest proportion of direct geothermal energy application in the world, but heat pumps have the greatest percentage of geothermal energy application as shown in Fig. 4. Geothermal-based heating and cooling systems consist of a heat pump, a ground heat exchanger (GHE) installed underground, and an air distribution system as shown in Fig. 5 [8-10].

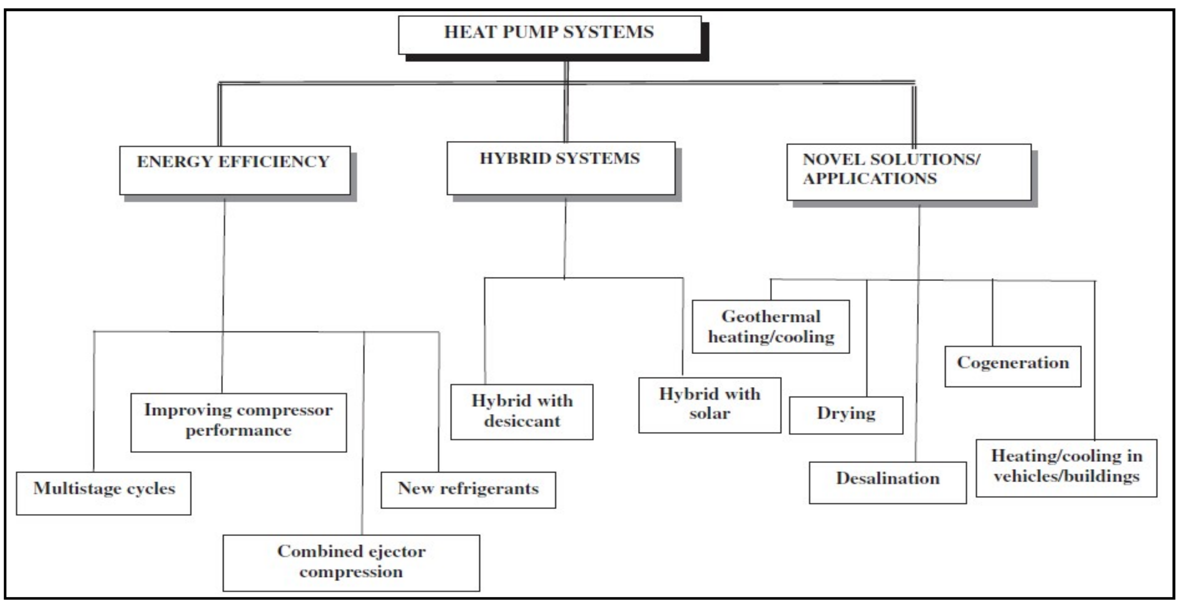

Fig. 2. Classification of heat pump systems.

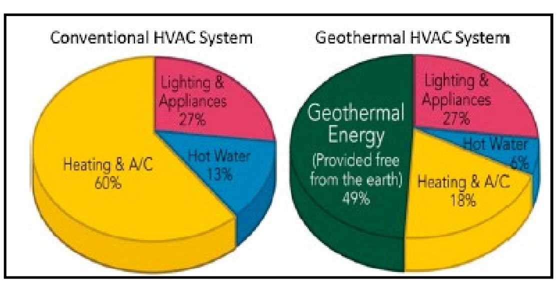

Fig. 3. Comparison between conventional HVAC and Geothermal heat pump systems.

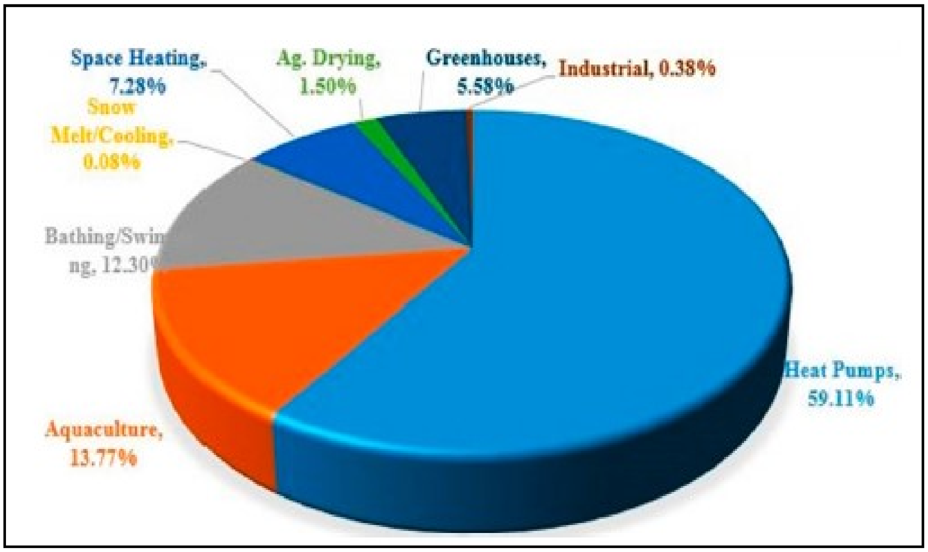

Fig. 4. Distribution of geothermal energy use in various applications.

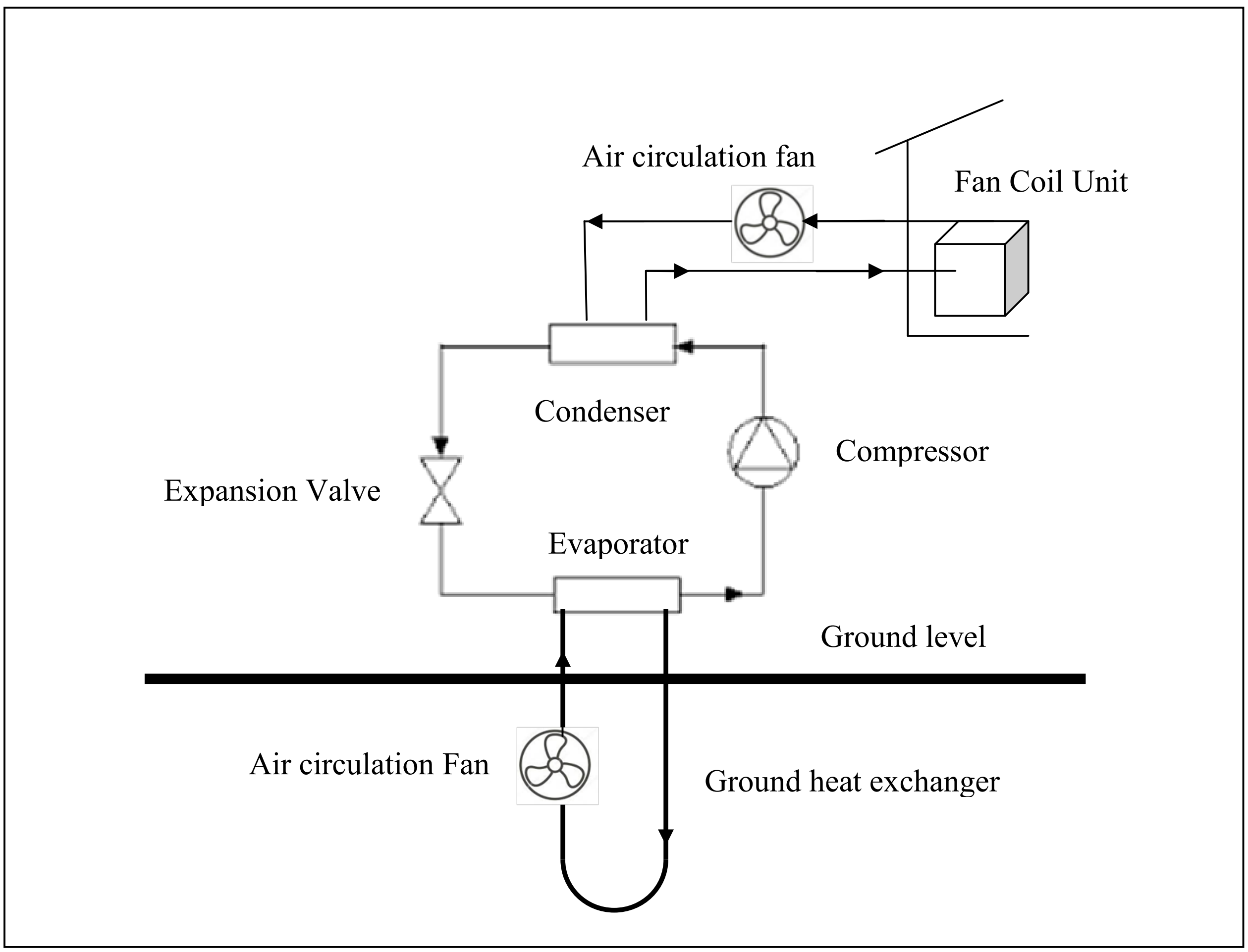

Fig. 4. Schematic diagram of ground source heat pump system.

For example, the annual change in temperature of the ground, with increasing depth, is shown in Fig. 5. As illustrated in this figure, ground temperature at 10-15 meter depth is roughly unchanging at nearly the average air temperature on a yearly basis for the change in season of environments [11-14].

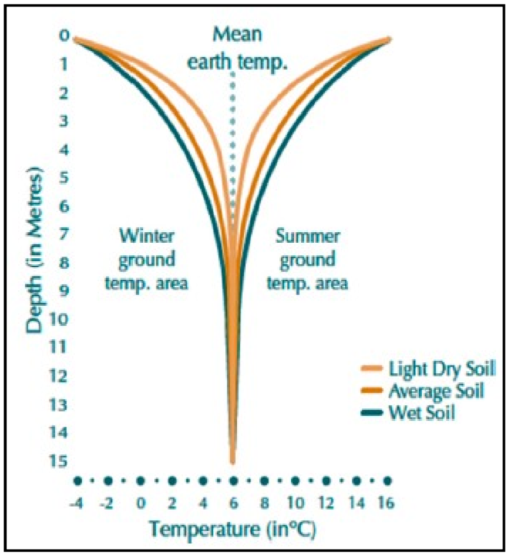

Fig.5.Conventional temperature changes with depth of earth.

When the difference between annual rejected heat to the ground and extracted heat from the ground is remarkable, as in extreme climates as opposed to temperate climates, the average ground temperature will increase or decrease over time, perhaps leading to changes in microbial environment and even the biological or organic matter reserves in the soil, or affecting the temperature of the water locally used for consumption. Fig. 6 shows such a decrease in average ground temperature because of the dominant heating period.

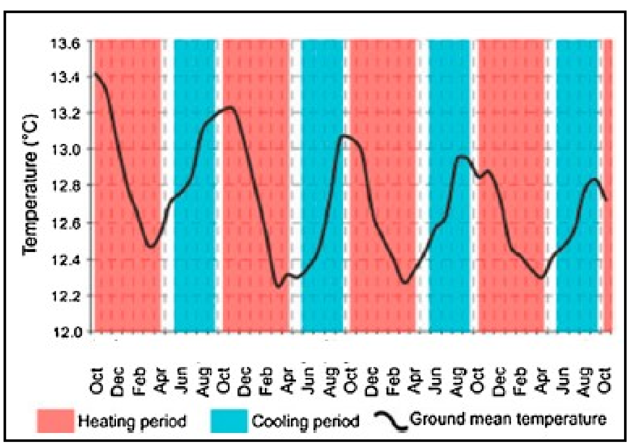

Fig.6.Variation in the temperature on yearly basis in GSHP.

III. SOLAR ASSISTED GSHP

In cooling dominated areas, excessive heat rejection can similarly result in a decrease in system performance. Similarly, the GCHP system alone can cause thermal depletion of the soil and a decrease in temperature of fluid entering the heat pump, in heating dominated climates. Extra heat load can be supplied by different supplemental sources, such as local sources of low grade wasted heat. The use of a supplemental heat absorber will likely decrease the total life cycle cost of the system more than the other types of GSHP systems. Fig. 7 depicts the layout of ground source heat pump system with solar thermal collectors. The application of combined geothermal and solar energy in heat pumps for heating in commercial applications has been studied since the introduction of geothermal systems. The use of a solar collector leads to a 37% decrease in heat exchanger size [15-20].

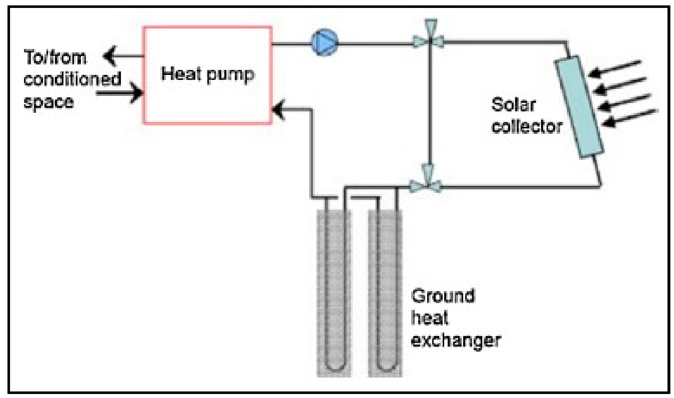

Fig.7.Layout of solar assisted GSHP.

IV. CONCLUSIONS

Ground source heat pumps are proven to be an efficient cooling and heating technology in space conditioning that allow for reductions in CO_2 emissions, the potential avoidance of fossil fuel usage and economic advantages. Heat pumps utilize significantly less energy to heat a building than alternative heating or space cooling systems. Many variations of ground source heat pump systems for heating and cooling the building have already been exist, with different configurations suitable in different situations and most locations around the world. In deciding among heating or cooling options, it is important to determine the benefits for different ground heat pump options, typically in terms of efficiency, emissions and economics.

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