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Space Heating and Cooling Application Based on Low Enthalpy Geothermal Reservoirs with a Focus on India Subcontinent

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ABSTRACT

With rapidly growing global energy demand and challenges like shortage of fossil fuels, the requirement for renewable energy as well as energy efficient systems are need of the hour. Moreover, with the global fraternity facing challenges like global warming, these systems should also be environment friendly. With focus on tropical countries like India, with diverse geographical conditions and different climatic conditions throughout the year, both heating and cooling requirements are there in domestic and commercial areas. In addition, India is focusing on renewable and unconventional sources like Solar, wind, biomass, tidal and geothermal energy. Keeping all of the above in consideration, this paper presents an integrated system of conventional ground source heat pumps (GSHP) with geothermal energy for Space heating and cooling for commercial, industrial and domestic applications. Also, the ground temperature remains more or less constant throughout the year, thus it provides a reliable heat source or sink for the operation of a heat pump. The uniqueness of the system is to produce large temperature difference between cooling side and heating side with utilization of minimal load. Designs of such systems are determined by the options of system configuration and control. The uniqueness of the system is to produce large temperature difference between cooling side and heating side with utilization of minimal load. The range of this ΔT is 60 degree Celsius to 65 degree Celsius. Moving one-step forward, apart from conventional heating and cooling, this system will function on higher temperature than conventional GSHPs to generate water at higher temperature, which can be utilized for small-scale power generation for remote and rural areas. This water is also utilized for direct applications such as green house, fish farming, spa, milk pasteurization etc. The cooling side is also utilized in air-conditioning system. The entire system is designed in such a way that we can use for any renewable application. It can be integrated or coupled with any of the systems such as organic rankine cycle, solar thermal system and biogas plant.

1. INTRODUCTION

Geothermal Energy, being a clean and sustainable source of energy is gaining importance worldwide due to various reasons. Geothermal power can be generated throughout the year on twenty four hour basis as it's not much dependent on ambient temperature and weather conditions. Also, it doesn't require much land area compared to other sources such as solar photo-voltaic cells and wind energy. Additionally, geothermal power plants do not emit any kind of greenhouse or toxic gases into the environment.

High enthalpy geothermal resources are generally utilised for indirect applications such as power generation. However, the scope of this paper is strictly focussed on low enthalpy geothermal resources with the context of Indian subcontinent. Most of the geothermal resources in Indian subcontinent are of low-enthalpy in nature. Because of geographical and climatic conditions of the area, solar and wind energy dominates the renewable energy sector. Hence, geothermal power generation has been largely ignored by the researchers industries and policy makers in India due to lo resources, high capital and operating expenditure compared to other conventional sources such as coal, oil and natural gas and renewable energy sources such as solar, wind and biomass energy.

However, recently there is an increased interest in exploitation of low enthalpy geothermal resources for other applications such as geothermal space heating and cooling for domestic, industrial and commercial applications. The system is designed using Ground Source Heat Pumps (GSHP), which utilises the earth as the heat source or heat sink. The geothermal space heating and cooling system is much more energy efficient and environment friendly technology. It reduces water requirements, chemical usage and emission of greenhouse gases. In countries like India, which faces problems such as acute water shortage,, increasing pollution, energy deficiency power deficit and dependency on imported fossil fuels, geothermal space heating and cooling can prove a game changer in the long run if applied on a large scale.

2. GEOTHERMAL ENERGY RESOURCES IN INDIA

Indian subcontinent comprises of large number of geothermal fields such as Tatapani Chhattisgarh; Puga Valley, Jammu and Kashmir; Dholera and Unai fields Gujarat; Chamoli, Uttarakhand to name a few out of the total 340 geothermal hot springs in India. There have been tremendous exploration activities have been carried out at these geothermal fields. However, there have been no commercial exploitation for power generation is yet to take place in India. The principal reason for this would be that the geothermal resources are of low enthalpy in nature. The surface temperature of the hot springs range from 30 degree Celsius to 100 degree Celsius. (Vaidya et al, 2015) Recently, there is an increased interest in utilising these geothermal resources for other applications such as space heating and cooling for domestic commercial and industrial purposes. Additionally there have been several direct applications such as fisheries, capsicum and tomato cultivation, crop drying, green houses and tourism etc. The scope of this paper is restricted to the discussion of Space Heating and Cooling using geothermal energy Chandrasekharam (2005)

3. CLIMATIC CONDITIONS OF INDIAN SUBCONTINENT

Before discussing the technical aspects of Space Heating and Cooling applications, it is important to understand the climatic conditions of India. On an average, climate of this geographic region is comparatively warmer than that of most parts of Europe and North America. Indian subcontinent has six different tropical seasons throughout the year. Geographically, Indian peninsula has a wide range of geographical features comprising of Himalayan glaciers, different mountain ranges, river eco-systems, deserts, coastal areas and forest ranges Indian peninsula has been divided over different climatic zones facing different tropical seasons throughout the year. Table 1 describes the classification of climatic zones in India, which are divided into Hot and Dry, Warm and Humid, Moderate, Cold and Cloudy and Cold and Sunny based on mean monthly temperate and relative humidity of the area.

Based on the respective geographic area and subsequent atmospheric conditions space heating and/or cooling requirements are decided. Broadly, major area of the subcontinent required space cooling for most part of the year.

Table 1: Classification of Climatic Zones in India Bansal et al. (1988)

Climate	Mean monthly temperature (˚C)	Relative Humidity (%)
Hot and Dry	>30	<55
Warm and Humid	>30	>55
Moderate	25-30	<75
Cold and Cloudy	<25	>55
Cold and Sunny	<25	<55
Composite	This applies, when six months or more do not fall within any of the above categories	

4. SPACE HEATING AND COOLING APPLICATIONS

4.1 Background

With increasing global warming and volatile temperature conditions throughout the year, requirement of artificial heating and cooling (air conditioning) has been increased recently. The air conditioning devices or plants/systems consume huge amount of electrical energy. In fact, it consumes largest share of the total power consumption of any domestic house hold or commercial building. Apart from higher power consumption, the conventional systems have several other drawbacks such as higher amount of water wastage due to evaporation, emission of green house gases, ejecting heat to environment leading to global warming and usage of hazardous chemicals. To overcome all these shortcoming, the concept space heating and cooling is developed. The paper discusses to the process of geothermal space heating and cooling by integration of geothermal energy and ground source heat pumps (GSHP).

4.2 Ground Source Heat Pumps (GSHP)

A GSHP is a device which functions on two simultaneous loops to provide parallel cooling and heating in an energy efficient manner. pump comprises of the most important part of the system. GSHP provides heat energy from a source of heat to a "heat sink". GSHP moves thermal energy opposite to the direction of spontaneous heat flow by absorbing heat from a cold space and releasing it to a relatively warmer space. A heat pump uses some amount of external electrical energy to fulfil the work of transferring energy from the heat source to the heat sink. Heat pump works on a dual loop namely condenser side (Heat source loop) and evaporator side (Heat Sink). Both the loops of heat pump are closed loop systems. In a close loop system, the working fluid or water circulates within the closed loop pipelines where no water loss is there. Hence, the system is designed in such a way that there is not water loss during the process. Dhale et al. (2015)

A heat pump based on vapour compression cycle consists four components namely an evaporator, a compressor, a condenser and an expansion device. Evaporator absorbs heat from the cold medium (Geothermal Loop), compressor pressurizes the refrigerant gas to a higher pressure. Heat is rejected to the hot medium (hot water in this case) and the expansion device equalizes pressure of the system thus completing the cycle. Efficiency of the heat pump is measured in terms of COP or Coefficient of Performance. COP is the ratio of heat produced to the work supplied at the compressor. In case of a hot water cogeneration heat pump, this COP can be measured as energy supplied to the hot water system divided by compressor input power Lund (2007).

4.2.1 Conventional GSHPs

Conventional GSHPs utilise the mother earth as either the heat source or the heat sink. The subsurface zone of the depth ranging from 10 m to 100 m is called as the undisturbed zone of the earth. Florides and Kalogirou (2004). The average temperature of this zone remains constant throughout the year. However, the temperature varies from place to place. In Indian subcontinent, this temperature is of the order of 27 degree Celsius. Therefore, in summer season, when the ambient temperature is around 45 degree Celsius, the subsurface zone can act as a heat sink and the target space (e.g. the building) can be used as a heat source. The situation will be vice-versa during the winter season, when the ambient temperature is of the order of 5-10 degree Celsius.

The ground temperature, in the subsurface, varies drastically with different depths. At the beginning of 0–10 m, the ground temperature is affected abruptly by climate. Below, between 10–100 m depth, the ground temperature is affected by both heat flux from deeper ground and air temperature. ASHRAE (1991). In general, the ground temperature within such depth keeps a constant temperature which is generally equal to the mean value of the ambient temperature over the year. Then, the temperature increases with increasing ground depth, and a linear relation between temperature and depth is observed, which is called thermal gradient. The mean temperature increases 2.5 ℃ with increasing depth of 100 m. Geothermal heat sink system uses the earth as heat sink instead of outside atmosphere in conventional systems. The earth temperatures in most cases are much lower than the atmospheric temperatures. With the lower temperatures the efficiencies of the air-conditioning systems are significantly higher.

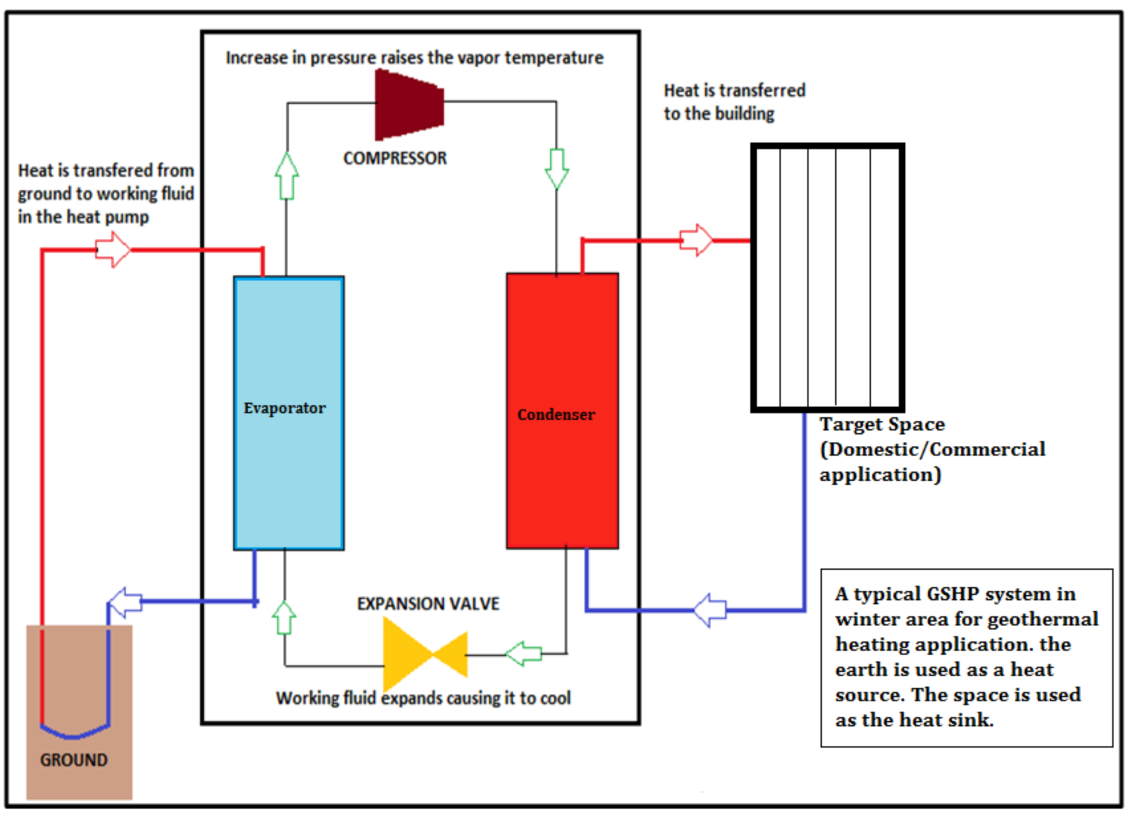

Figure 1: Conventional Ground Source Heat Pump System

Figure 1 describes the conventional GSHP system for space heating during the winter season. In this system, the earth subsurface (the undisturbed zone) is utilised as the heat source and the target space (domestic households/commercial buildings) is utilised as the heat sink. Both the heating and cooling loops being closed loop systems, there is not wastage of water in the system. However, during practical implementation, some amount of leakages is there in the system. To compensate, a make-up water supply is provided to the system to ensure smooth functioning of the plant.

4.2.2 GSHPs based on Low Enthalpy Geothermal Resources

This system utilises energy directly from the hot water, which is produced from the geothermal well at the heat source side (evaporator side) of the GSHP and transfers the heat to the heat sink side (condenser side) of the GSHP. Also, the systems works on two different loops on heat source side on different temperature ranges. Lastly, the output on the heat sink side of the heat pump is significantly higher than the conventional GSHP systems. The system is specially optimised to increase the temperature of the water produced from the geothermal well and simultaneously provide comfort cooling for domestic or industrial applications.

Figure 2 describes the simultaneous space heating and cooling system based on GSHP using geothermal energy. Instead of the undisturbed zone of the earth, it utilises the hot water produced from the geothermal well as the heat source. In this system, the heat sinks are the target space for space heating or process heating. This depends on the requirement of the hot water. The temperature of the water from the outlet of the heat pump is considerably high than that of the produced water from the geothermal well. Apart from space heating, the produced hot water can be utilized for various purposes such as pilot scale power generation or direct applications in agriculture sector.

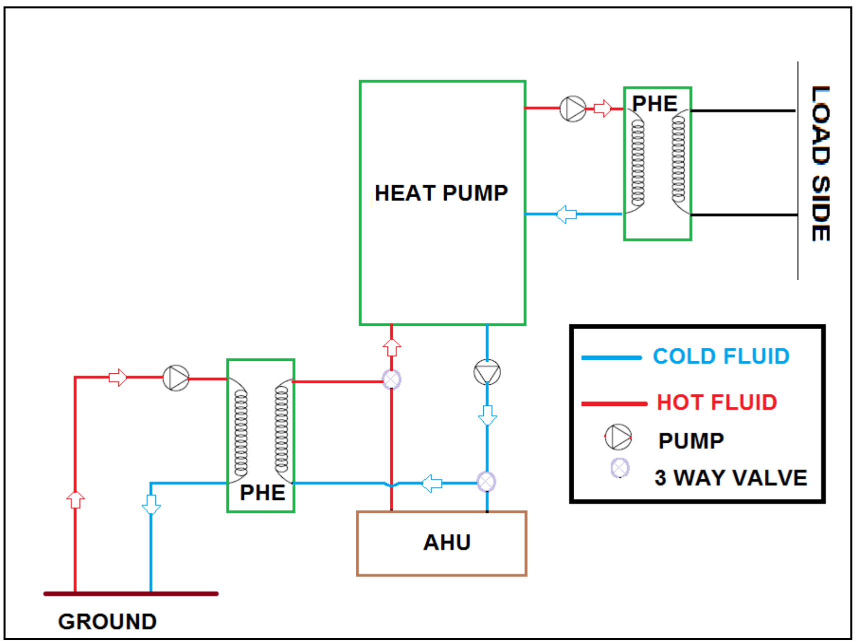

Figure 2: Ground Source Heat Pump system based on low enthalpy geothermal resource

5. CONCLUSION

In this paper, two types of space heating and cooling systems were discussed based on Geothermal Energy. The principal objective of Geothermal heating and cooling systems is to reduce the consumption of electrical energy in domestic or commercial buildings. On an average, 40% of electrical energy is saved compared to the conventional heating and/or cooling systems. The capital expenditure of such systems is higher than the conventional systems. However, due to significant energy savings operational expenditure is considerably reduced. The payback period of Geothermal systems is of the order of 3 years. Apart from reduced power consumption these systems have several other benefits. In GSHP systems, both the heating and cooling loops are closed loops, hence there is no water wastage compared to conventional cooling or heating systems where water is evaporated in open loop systems. Additionally, no greenhouse gases are emitted in such systems. Due to lower electrical consumption, utilization of fossil fuels is considerably reduced.

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