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Contribution of Geothermal Energy for Air Conditioning Applications on Electric Energy Consumption

A Thesis Submitted to Council of College of Engineering, University of Diyala in partial of fulfillment of the Requirements for the Degree of Master of Science in Mechanical Engineering

By

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بسم الله الرحمن الرحيم

كَمَا أَرْسَلْنَا فِيكُمْ رَسُولاً مِّنكُمْ يَتْلُو عَلَيْكُمْ
آيَاتِنَا وَيُزَكِّيكُمْ وَيُعَلِّمُكُمُ الْكِتَابَ
وَالْحِكْمَةَ وَيُعَلِّمُكُم مَّا لَمْ تَكُونُوا تَعْلَمُونَ
(١٥١) فَاذْكُرُونِي أَذْكُرْكُمْ وَاشْكُرُوا لِي
وَلَا تَكْفُرُونِ (152)

صدق الله العظيم

سورة البقرة (الأية ١٥٢)

To:

The dearest person in my life, who spent his life in taking care of his family: my dear father.

The candle that makes my life lightened: my dear mother.

The person who stands by me, helps me: my wife.

My lovely sons and my daughter who make my life valuable.

All persons who gave me a hand in doing this work.

Hazim N. Abed

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I also thank my family who encouraged me and prayed for me throughout the time of my research.

Hazim N. Abed

Supervisor Certificate

I certify that this thesis entitled **(Contribution of Geothermal Energy for Air Conditioning Applications on Electric Energy Consumption)** had been carried out under my supervision at the University of Diyala / College of Engineering - Mechanical Engineering Department in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering.

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Date: / / 2021

In view of the available recommendation, I forward this thesis for debate by the examination committee.

Signature:

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Examination Committee Certificate

We certify that we have read this dissertation entitled **(Contribution of Geothermal Energy for Air Conditioning Applications on Electric Energy Consumption)** and as an examining committee examined the student (**Hazim Najim Al-Deen Abed)** in its contents and that in our opinion it meets standard of a thesis and is adequate for the award of the degree of Master of Science in Mechanical Engineering.

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ABSTRACT

The use of geothermal as one of the important energy alternatives that has increased interest in facing the excessive use of fossil fuels as a main source of energy. The excessive use of fossil fuel is the main cause of climate change in the world as a result of greenhouse gas emissions. One of the most important applications of geothermal is its use in the heating and air – conditioning sector in residential and commercial buildings, as well as in the electric power generation sector, especially in depths that reach a temperature of more than 200°C. In this study, geothermal energy was used in the application of air – conditioning and knew its effectiveness in reducing electrical energy consumption compared to traditional systems in the city of Baqubah. A geothermal system was used with a window type air conditioner of a two tons refrigeration capacity to find out the contribution of using geothermal energy in reducing the electricity consumption. The study is a comparison with traditional air conditioning systems. Electricity consumption was calculated for three scenarios: the geothermal system alone, the traditional air conditioner system (A/C) alone, and the combined system (the geothermal system and A/C system).

The coefficient of performance factor (COP) and energy efficiency ratio (EER) were calculated for the three approaches 5.54, 18.9, 1.52, 9.383, 1.87, 9.8 respectively. The results obtained from the study have demonstrated the possibility of benefiting from geothermal energy in air conditioning applications in Iraq and reducing electricity consumption by reducing dependence on traditional air conditioning systems. The reduction in energy consumption for the summer season was by 12% to 15% for the combined air-conditioning system, while when using the geothermal system alone in the winter season, the reduction in energy consumption was by 87%.

Finally, these finding may approve that, the geothermal system can be used as an auxiliary in summer season to decrease electric energy consumption by 15%. Moreover, in winter, the geothermal system alone guarantee the comfort condition most of the season (T_{indoor} = 22°C and RH= 60%

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NOMENCLATURE

SYMBOLES	DESCRIBTION	UNITS
A	area of solid perpendicular to the direction of heat transfer	m^2
A_c	cross sectional area	m^2
A_{tube}	surface area of tube or wall	m^2
a	thickness of air cavities	$w/m^2.°C$
$C_1, C_2, .., C_n$	conductance factors	$w/m^2.°C$
C_P	Specific heat capacity	W.s / kg. °C
CLF	cooling load factor	
CLTD	cooling load temperature difference	°C
$CLTD_c$	corrected cooling load temperature difference	°C
EER	Energy Efficiency Ratio	(Btu/h)/W
f	attic factor	
f_i, f_o	indoor and outdoor air film coefficients respectively	$w/m^2.°C$
H	the depth below the ground surface	m
h	heat transfer coefficient	$w / m^2 . °C$
h_e, h_{in}	enthalpy exit and enthalpy inlet respectively	kJ/kg
h_i,h_o	Indoor, outdoor enthalpy	kJ/kg

K	Color correction factor	
k	thermal conductivity of material	w / m . ºC
LM	latitude and month correction factors	℃
$\dot{m}$	mass flowrate	kg/s
$\dot{m}_1$	inlet mass flowrate	kg/s
$\dot{m}_2$	outlet mass flowrate	kg/s
Q_H	heat transferred to a heated zone	Watt
Q_{out}	output heat transfer rate	Watt
q_x	heat transfer rate	W
R_t	overall resistance of wall	m^2.℃/w
SC	shading coefficient	
SHG	solar heat gain	w/m^2
T	temperature	℃
T_e, T_i	temperature at exit and inlet	℃
$T_{fluid,av}$	average fluid temperature	℃
T_H	high temperature	℃
T_L	low temperature	℃
T_m	mean ground temperature	℃
T_O	average outdoor temperature	℃
T_o	the annual mean air temperature	℃
T_R	room temperature	℃

T_w	wall temperature	℃
$T_{w,av}$	average wall temperature	℃
$T\infty$	fluid temperature	℃
t_b	unconditioned space temperature	℃
t_i , t_{in}	indoor temperature	℃
t_o	outdoor temperature	℃
U	overall heat transfer coefficient	w/m^2 ℃
u_{mean}	mean fluid velocity	m/s
V	average air infiltration	m^3/s
v	Fluid velocity	m/s
W	work consumed by the system	Watt
W_{in}	input work	Watt
x_a, x_b, x_1, x_2, .., x_n	wall layers thicknesses	m
ρ	fluid density	kg/m^3
$\sum R_t$	overall thermal resistance	℃/w
ΔT	temperature difference	℃
Δx	thickness of solid	m

ABBREVIATIONS

Abbreviation	Definition
GHGs	Greenhouse gases
CO_2	Carbon-dioxide
GSHP	Ground source heat pump
GSHPS	Ground source heat pump system
A/C	Air-conditioner
EFT	Entering liquid temperature
NPV	Net present value
PBT	Payback time
GHP	Geothermal heat pump
TRNSYS	Transient System Simulation
HVAC	Heating Ventilating and Air Conditioning
GCC	Ground coupled condensers
GHXs	Ground heat exchangers
COP	Coefficient of performance
SWHPs	Surface water heat pumps
GLD	Ground-Loop Design
GWHP	Ground water heat pump
GCHP	Ground coupled heat pump
COPs	Coefficient of performances
$E_{thermal}$	Thermal energy
$E_{electricity}$	Electrical energy
$T_{outdoor}$	Outdoor temperature
T_{indoor}	Indoor temperature
COP_{sys}	System coefficient of performance
HP	Heat pump
ASHP	Air source heat pump

C/D	capacity to demand
GHE	Ground heat exchanger
ICE	Internal-combustion engine
CHP	Combined heat and power
CDERR	CO_2 emission reduction ratio
ASHRAE	American Society of Heating Refrigerating and Air conditioning Engineers
GCHPS	Ground – Coupled Heat Pump System
HDPE	High Density-Polyethylene
SWHP	Surface-Water Heat Pump
SCW	Standing Column Well
DOE	Department of Energy
RTS	radiant-time series
HB	heat-balance
PV	Photovoltaic
Btu	British thermal units
EER	Energy Efficiency Ratio
MJ	Mega Joule
TWh	Tera Watt-hour
kJh^{-1}	Kilo Joule per hour
NT$	New Thailand Dollar
GWHPS	Ground Water Heat Pump System
kW	Kilo Watt
RW-PU	Radiant Wall-Panel Unit
R-FCU	Radiator-Fan Coil Unit
FH-FCU	Floor Heating-Fan Coil Unit
ESR	Energy Saving Ratio
ACSR	Annual-Cost Saving Reduction

H.Ex	Heat Exchanger
FLT	First Law of Thermodynamics

CHAPTER ONE

INTRODUCTION

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INTRODUCTION

1.1 INTRODUCTION

Cooling and heating for residential, commercial, and industrial buildings are consuming a big portions of energy. The energy costs is an important factor. One of the energy consumption side effect is greenhouse gases (GHGs) emissions, which cause global warming [1, 2].

In another hand, the increasing in demand for fossil fuel will accelerate depleting it in about 60 years or less [3]. Moreover the world crises and problems like energy crisis in the seventieths of twenty century, Arab gulf crisis, the Middle East crisis, danger of nuclear power plants, and global warming. All these reasons have urge many consumers countries for fossil fuels to find solutions and cheap alternatives. These solutions are the sustainable, ocean, offshore, tides, solar, wind, biomass, hydro, and geothermal energies.

These alternatives have many advantages as bellow:

1- Abundant and multi –resources.
2- Cheap for long –term and low risks.
3- Environmentally friendly, low pollution, low greenhouse gases (GHGs) emissions [2, 4, 5].
4- Energy saving [5].

The good examples for little to no GHGs emissions are the systems that use the sustainable energy like solar, biomass, wind, hydro, and geothermal energies [4].

The thermal energy stored in the earth was estimated about 12.6 * 10^{24}MJ, and 5.4*10^{21}MJ (1.5*10^{12} TWh) of thermal energy in the crust of earth [6]. Natural gas and electricity utilization represents practically 50% of the necessary energy in Canada [7]. Cooling and heating commercial and residential buildings in Canada consume a large amount of energy required for buildings, about 60%, and this requires finding quick and effective solutions to reduce energy consumption [8].

The use of hot springs in heating was economic. The consumed electrical energy in the building was reduced about 26%, the A/C heating systems was decreased by 54% of electric energy, and the reduction in electricity consumption by the air host is 66.5%. Expenses 126.7New Thailand Dollars(NT$) will produce 1kg of carbon-dioxide (CO_2) emissions [9].

1.2 GEOTHERMAL ENERGY

The energy saved under the surface of the earth is known as geothermal energy. Although the huge energy potential of geothermal, but actually a small portion of it can be utilized. The increasing depth into the crust of the earth will cause increasing in pressure and temperature, so that the utilized geothermal energy will be more efficient. The Low-Enthalpy forms of energy are found in geothermal resources that have temperatures under or equal to 200°C, and it is suitable for direct –heating applications; and High-Enthalpy forms where temperatures more than 200°C are suitable for producing electricity [6, 10]. The temperature under earth surface at specific depth is relatively constant for all days of the year and this depth varies depending on the geographical location. Ground source heat pump (GSHP) systems is an umbrella term used for a group of diverse systems that use groundwater, ground and surface water as a heat sink or source to provide the spaces cooling or heating and utilize the hot - water for domestic applications. GSHP is divided into three types according to the type of external heat exchange system, which are GWHPs, GCHPs and SWHPs[11]. GSHP invention can provide a higher energy proficiency for cooling and A/C system contrasted with traditional A/C frameworks in light of the fact that the underground climate gives low- temperatures for cooling and high- temperatures for heating and encounters less temperature vacillation than encompassing air [10].

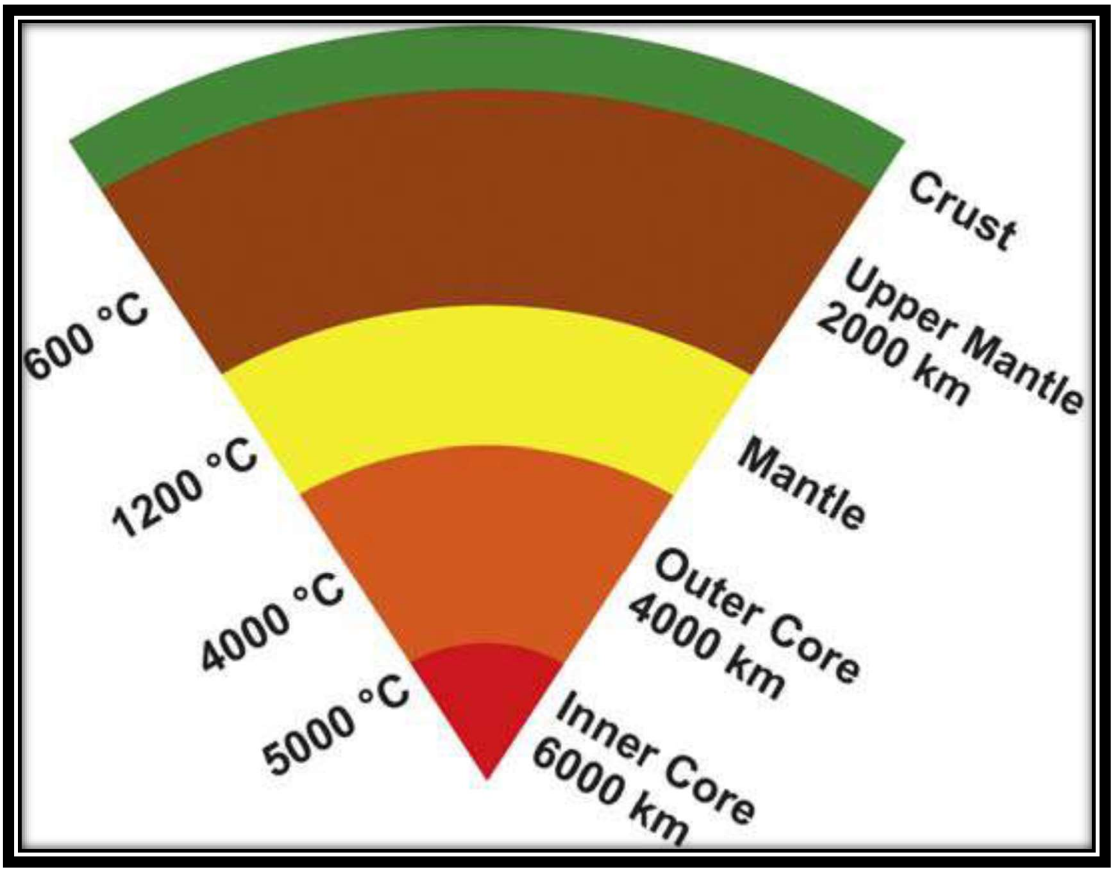

Figure (1.1) Structure of Earth's interior[12]

Advantages of GSHP Systems [13]:

1- Small space requirements.
2- Aesthetics (no outdoor equipment).
3- Easy to operate and control.
4- Simplicity.

5- Comfort.
6- Low repair and maintenance requirements.

Disadvantages of GSHP Systems [13]:

1- Profit is limited for manufacturers of HVAC equipment.
2- Application of GSHP is new and innovative.
3- High initial cost.

1.3 APPLICATIONS OF GEOTHERMAL FOR COOLING AND HEATING

The high initial costs and long payback period of GSHP systems are the main factor in their lack of wide spread in the local market. Much of the time, market entrance impedance for GSHP frameworks can be eased with the utilization of proper computational devices for configuration investigations. Improving the financial standpoint of potential establishments can be tended to by hybridizing GSHP frameworks with a helper framework; the structures base burden requests are met by the GSHP.

Framework and any extreme pennacles are met by a helper framework. Because of the exceptionally factor nature of measuring GSHP frameworks, general principals presently utilized by the business don't generally relate to a streamlined plan. Trending to the issue, built up another computational methodology, supplanting the dependable guideline strategy for estimating crossover GSHPS[14, 15].

The technology of GSHP systems is an alternative energy technology that is distinguished from traditional heating and cooling systems by being environmentally friendly. This has led to its increasing spread in the commercial and industrial markets and not limited to the residential buildings market only. One of the main reasons why GSHP systems are so unattractive compared to traditional alternatives are the often high initial costs, long payback period and low return on investment. To reduce the initial costs of GSHP systems and make them more economically feasible, hybrid GSHP systems are used, which is an important solution. To meet the needs of the basic loads, hybrid GSHP systems are used, and to complete the peak requirements, traditional systems are used. In a hybrid system the capacity of the GSHP is determined by following approximate thumb rules where calculations are made to test its economic viability. The process currently used to determine GSHP capacity is neither optimal nor mathematically rigorous. A rigorous computational and mathematical approach to determine the size of GSHP within hybrid systems was used. In its methodology, this study relied on testing ten cases of residential, commercial and industrial buildings. Significant reductions in initial installation costs, reduced payback period, and reduced operating costs can be obtained when using this methodology compared to the following basic rules or if non-hybrid air conditioning systems are used. The improvement in most cases makes GSHP systems economically viable as they meet a very large part of the annual demand for cooling and heating of buildings, usually estimated at more than 80%[14]. For instance, in Sagia et al's. Study, the cooling tower (assistant cooling framework) was measured to meet 20%, 30%, and half of a specific structure's cooling load [15], with the equilibrium met by a GSHP. Paradoxically, the strategy proposed by Alavy et al. naturally estimates the warming and cooling frameworks, meeting the structure's pinnacle cooling and warming burdens, with consistently factor assistant framework limit. The most affordable plan is chosen dependent on the least net present estimation of capital and working expenses. Since this procedure was grown as of late is still ineffectively comprehended, a huge information hole exists on how best to apply these new methods[14, 16].

Yong Wang et al. [17] proposed an enhancement of open-loop, surface water heat pumps (SWHPs) efficiency by improving the design of intake water. The water temperature at inlet is important factor that effect on energy efficiency of the SWHPs. This study suggested a two design methods to enhance SWHPs efficiency. A comparison and analyzing was made between the numerical model, which concerns to a SWHPs parameters such as energy consumption and intake temperatures of fluid. The results show that, the amount of energy consumption, decreasing the water velocity at delivery has no important effect, while using multi- intake ports will increase the efficiency.

Debasree Roy et al. [18]presented an investigation of performance and feasibility for vertical GSHP systems that used for cooling and heating application. The building area was $9000m^2$ with subtropical and tropical climate. The study use the Ground-Loop Design (GLD) software to perform the GSHP systems design for every location, and use the Energy-Plus v9.0.1 software to simulate the cooling and heating loads of the building. Assessing the installation of GSHP system feasibility from point of view economically by using the multiple years cost analyzing. It found that in tropical climates especially near equator the GSHP systems where used in the cities may not be economically feasible due to high-cooling demand and insufficient performance. The system exacerbation in tropical cities are caused by the soil thermal imbalance due to the greater demand for cooling and heating. To overcome the problems of GSHP in tropical cities near the cancer tropic, special design techniques must be developed or adding sources of hybrid energy. Where the balance happens between the cooling and heating loads in subtropical climate cities, GSHP systems will be economic and efficient. This study used ten cities in different places in the world, subtropical and tropical climates, and different soil properties [18].

In Iraq, Ahmed Al-Samari and Sameer D. Ali conducted an experiment to evaluate the effectiveness of surface geothermal energy in air-conditioning applications. The study proved the possibility of using geothermal energy to obtain a good difference in temperature between outdoor and indoor by about 18°C. Moreover, the use of geothermal system alone does not achieve the comfort condition of 25°C and relative humidity of about 55%. On the other hand, it achieved a reduction in electricity consumption by 60%[19].

In this study, the combined air-conditioning system (Geothermal system and Window type air-conditioner) will be used and its effectiveness in decreasing electrical-energy consumption will be known.

1.4 OBJECTIVE OF THE PRESENT WORK

1. Studying the use of geothermal energy in air – conditioning and its effect on electricity consumption in residential sector.

2. Studying the effect temperature and relative humidity on electrical energy consumption.

3. Carrying out design calculations on the heat exchanger used in the geothermal system.

4. Calculate COP and EER for three air – conditioning systems, geothermal system, combined system (geothermal system and traditional air– conditioning system) and conventional air – conditioning system alone in heating and cooling seasons.

5. Using HAP 4.9 software in calculating the thermal loads and simulating the systems in air – conditioning and their annual electricity consumption for the studied space.

6. This study aspire to investigate the benefit of using the shallow depth geothermal energy for cooling and heating application in residential buildings in hot severe climate in summer and cold climate in winter.

1.5 Thesis outlines

❖ The first chapter is an introduction to the traditional energy used in cooling and heating, the global crises that affected it, and the use of geothermal energy as one of the inexpensive alternatives to renewable energy.

❖ The second chapter provides a brief explanation of some literary studies and their findings on the use of underground energy and its most important applications and contributions to reducing the use of fossil fuel.

❖ The third chapter deals with the theory and governing equations that used in this thesis and the important laws, equations, formulas, and simulating program.

❖ The fourth chapter shows the methodology in research of where the location of the site and the equipment used in the geothermal system and the method of getting results.

❖ The fifth chapter shows the details of the results as charts, tables and graphs of the data in addition to the discussion of these results.

❖ The sixth chapter present a conclusions for this work and some suggestions to the future works.