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GROUND SOURCE HEAT PUMP SYSTEMS AND PUMP EXCHANGER SYSTEMS IN JORDAN

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Abstract. *This paper aims to study the potential of renewable energy sources systems in Jordan by analysing the use of the Ground Source Heat Pump Exchanger Systems. The paper discusses appropriate design and relates issues. Our focus, in this study, is the Shallow Geothermal Systems, depending on the ground loop that exchanges heat with the earth using the interior heat pump units that transfer heat between the ground loop and the conditioned spaces of a building. How quickly the system costs pay off depends in part on each system's heating and cooling requirement, that's means that unlike drilling for shale oil, geothermal energy is considered to be one of the cleanest, most efficient and safest forms of renewable energy.*

1 INTRODUCTION

Renewable energy technologies have been developing over the past years and have become more important. The use of energy from renewable sources is new in Jordan however, it is increasing. The state adopted and submitted a National Renewable Energy Action Plane with target the 2020. The National Energy Research Center has been established in Amman – Jordan for the purposes of research, development and training in the fields of new and renewable energy [1] .

Our discussion is focus in the study of the Shallow Geothermal Systems in Jordan, depending on the ground loop that exchanges heat with the earth using the interior heat pump units that transfer heat between the ground loop and the conditioned spaces of a building. A geothermal heat pump uses the constant below ground temperature of soil or water to heat and cool for buildings and we discuss appropriate design and relates issues.

Previous research shows that Jordan has enormous underground energy resources in many parts of the country in the form of thermal underground hot, having a temperature ranging from 20°C to 62°C (Swarieh, 2000) [2]. Two main areas are known, The first region is in immediate vicinity of the east Dead Sea escarpment, where many springs discharge thermal water originates from the Lower Cretaceous Sandstone. The second one is near the border with Syria and Iraq. In this region several thermal wells discharge water from the Upper Cretaceous Limestone. It was also found that the installed capacity of geothermal energy is 153.3 MWt and the annual energy supply potential is 1540 TJ/year in the form of domestic hot water for bathing and swimming, giving an overall capacity factor of 0.42. Geothermal energy can be used for absorption refrigeration to preserve fruit and vegetables or freeze fish and meat, as well as fish farming and greenhouse heating. There is no electrical use in the country from these resources.

2 GROUND SOURCE HEAT – PUMP EXCHANGER SYSTEM

A geothermal heat pump uses the constant below ground temperature of soil or water to heat and cool for buildings. Geothermal heat pumps (GHPs), sometimes referred to as GeoExchange, earth-coupled, or water-source heat pumps coupled, ground-source, or water-source heat pumps, have been in use since the late 1940s[3]. They use the constant temperature of the earth as the exchange medium instead of the outside air temperature. A GHP system, in its most basic elements, consists of a thermal source/sink (e.g., the earth, a pond, etc.), a heat pump (typically located inside the building), and a thermal output system to heat or cool the building space and/or heat water. In heating mode, the GHP pulls heat from the earth and transfers this heat to the indoor air or water; in cooling mode, the heat pump pulls heat from the indoor air and rejects the heat into the ground[4]. Figure 1 shows these system elements.

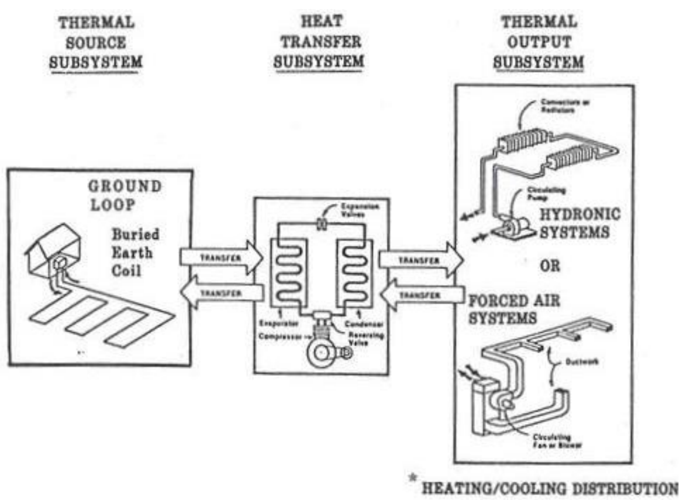

Figure 1: Basic Ground Source Heat Pump Components [5]

2.1 TYPES OF GEOTHERMAL HEAT PUMP SYSTEMS

There are four basic types of ground loop systems. Three of these horizontal, vertical, and pond/lake are closed-loop systems. The fourth type of system is the open-loop option. Which one of these is best depends on the climate, soil conditions, available land, and local installation costs at the site. All of these approaches can be used for residential and commercial building applications. Photo1 shows lay-out of horizontal close loop.

The winter absorbs heat from the ground to a high thermal load time and attaches to install, while the summer transfer high in relation to the earth, thermal load from the conditioned space to the ground, which can absorb, making the cooling of the space.

2.2 DESIGN DISCRIPTION FOR GSHPS SYSTEMS IN JORDAN

The first installation in the region was in Ramallah City (Palestinians Authorities) which was supervised by the International Ground Source Heat Pumps Association and European Union's MED-ENEC that has a 23kW cooling load and a 21kW heating load. There, annual heating and cooling costs have decreased from $9,100 to $2,960, which amounts to a staggering 70% energy savings.


Photo 1: Horizontal loop for heat exchanger

How quickly the system costs pay off depends in part on each system's heating and cooling requirement, that's means that unlike drilling for shale oil, geothermal energy is considered to be one of the cleanest, most efficient and safest forms of renewable energy.

The American University of Madaba in Jordan (AUM), owned by the Latin Patriarchate of Jerusalem and blessed by the Pope, has installed about 1.4MW for heating and about 1.7MW for cooling system. The system comprises a unit for the College of Science Building (A) and the college of Business Building (B). Photo 2 shows the first drilling stage of the vertical heat exchanger of the AUM geothermal system and figure 2 shows the close loop of the system with connection to the building.


Photo 2: Construction of the AUM geothermal system (Vertical heat exchanger)

Construction (AUM) geothermal system began in July, 2010 and involved drilling 422 boreholes in a vertical configuration 100 meters into the ground.

The former has a cooling load of 291 ton and heating load of 251 ton, while the latter has a 189 ton cooling load, and a 134 ton heating load. What this means is that every year the University will save 200,000 kWh electricity and 100,000 litres of diesel fuel, and all this with zero emissions. The ground source heat pump system installed at the American University of Madaba- Jordan is located at a distance of 39 km from Amman. The system of GSHPs serves the College of Science Building (A) and the college of Business Building (B) and includes classrooms, Laboratories, Cafeterias and Administrative Offices.

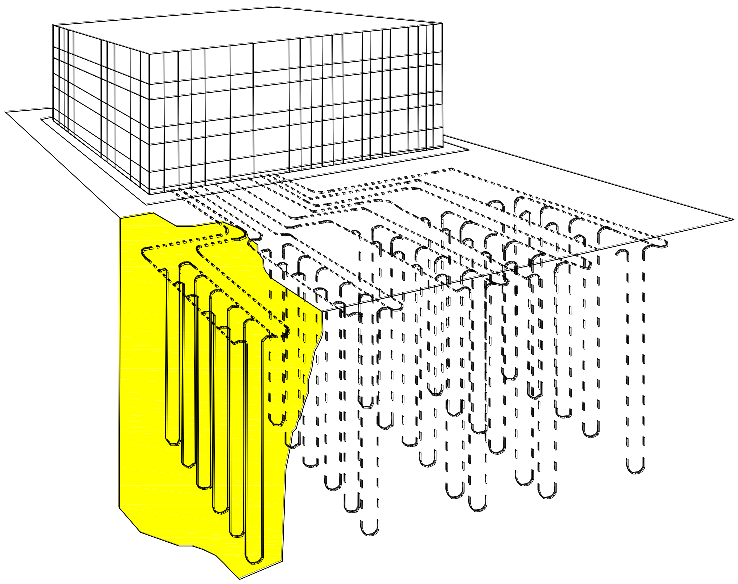

Figure 2: Close loop system of AUM

On average, the system is in operation 330 days per year, from 07:30 until 17:00. During the design phase, the total heating load was calculated at 880kW for building A and 480kW for Building B. The total cooling load was 1020kW for the building A and 660kW for building B.

The observed significant difference between heating and cooling loads is mainly due to the high solar loads, and is typical for office buildings in Jordan. During intermediate seasons (autumn and spring), due to the shape and orientation of the building, a requirement for the simultaneous heating and cooling of different parts of it is observed. Design conditions for heating is 21 degrees dry winter with 50% relative humidity and design conditions for cooling is 23 degrees dry Summer with 50% relative humidity.

The system is using Central Air Handling Units (AHUs) with water coils provide supply air to the building B and FCU units for heating and cooling (Building A). In terms of their connection to the hotchilled water loops, the fan-coils are organized in groups, based on the operation and the thermal characteristics of the room they serve. As a result, fan-coil loops are formed, serving building areas with similar thermal behavior and operation profile.
Two stage water to water heat pumps are used. The heat-pump systems are capable for totally independent operation, meaning that, depending on the requirements of the zones they serve, some of them may provide heating while the other loops provide cooling. 22 Central Air Handling Units (AHUs) with water coils +15 indoor Fan Coil units – Two pipe type- provide supply air to the building B and 85 FCU units–Two pipe type plus one AHU provide the supply air to the Building A.

A total of 26 heat pumps units are installed, 10 serving the fan-coils as well as the AHUs in Building B and 16 heat pumps units are installed serving the FCU and the AHU in Building A. The cooling capacity of each heat pump group is 68 kW, (matching heat pump units). The heat pumps of each group are connected in-parallel and operating under common control. The following GSHPs charts (figures 3 and 4), represents the two unit systems for building A and building B respectively. Also the photos 3 and 4, represent the collector for underground source and heat-pump configuration at AUM, respectively.

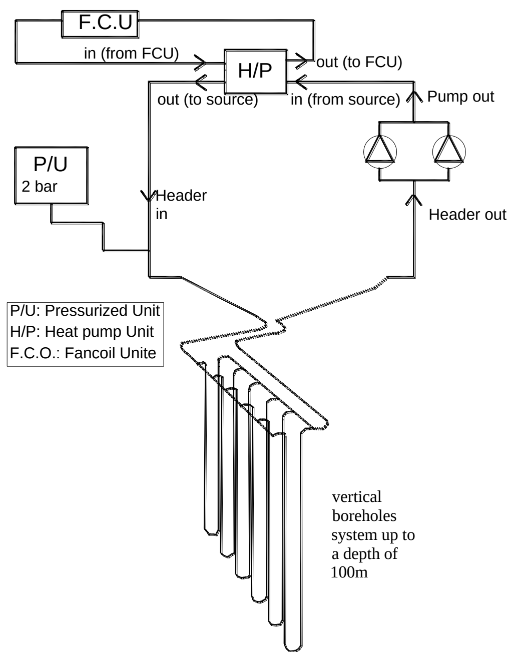

Figure 3: GSHPs charts at College of Science, Building (A)

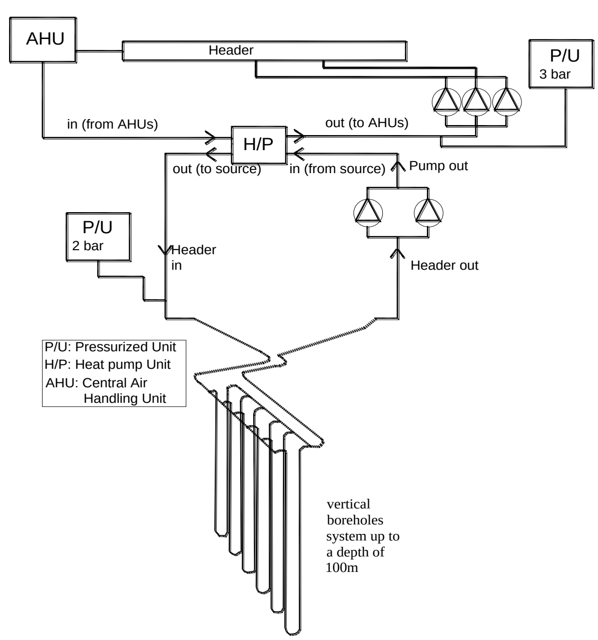

Figure 4: GSHPs charts at college of Business, Building (B)

422 vertical boreholes (165 building B + 257 building A) up to a depth of 100m make up the ground heat exchanger for each building respectively. Each borehole features a 1" internal diameter HDPE PE100 tube with a single U-shape. The primary circuit fluid is deionized water. In order to promote the thermal conductivity between the U-tubes and the surrounding soil, a special grouting mixture was used.

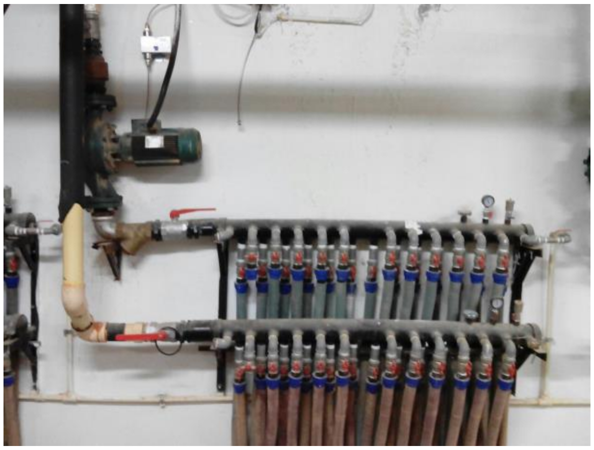

Photo 3: Source collectors (bottom) and Return collector (top) at AUM with AAV, pressure gage and Temperature gage

Photo 4: Heat Pump configuration (AUM)

A central BACNET is also foreseen, to fully control the operation of all the devices and networks of the system and also to provide system monitoring. An external data-logging system has also been installed, simply for monitoring the behavior of the whole installation.

3 CONCLUSIONS

The properties of the heat pump exchanger in AUM, which reflect the situation in Jordan, are the following:

- The underground constant temperature of earth is 16ºC.
- The maximum ground loop water temperature is 21–23°C $\pm$ 1 on average all year long.

- The mean lowest water temperature at the heat exchanger outlet is in the order of 16 – 17°C in heating mode and the highest is around 28-30°C in cooling mode, ± 2 in both cases.
- The efficiency of the system, especially in heating mode, is high, the week-average COP reaching 6.0 at an average ambient temperature of 10°C. The corresponding figures for air-to-air and air-to-water are 2.5 and 3.5, respectively, under similar conditions.
- In cooling mode, the week-average COP is 4.5, higher than that of the air-to-air (2.8) and the air-to-water (3.3) at 30°C average ambient temperature.
- It is worth mentioning that the observed COP is not directly related to the ambient temperature, with differences as high as 10°C having a practically negligible effect.

4 RECOMMENDATIONS:

The use of this types of system in hot areas of Jordan (Aqaba and Jordan Valley) is more effective than other areas, because the underground temperature maintains at 16ºC. The presence of water near the surface is important, but in all cases, we must get greater depth, so that we can maintain a constant temperature.
In addition to all above, an important economic benefit, can be approved, when we can use other renewable energy systems as solar energy, to operate the GHPs system.

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