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Inter-Seasonal Heat Storage

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***Abstract*—Summer heat is potentially one of the largest energy sources in many countries but to be useful it needs to be stored until the winter, preferably without the need for expensive and inflexible district heating systems. It is proposed that the summer heat can be injected into the ground beneath each individual property in a way that prevents it from flowing out into the neighbouring properties, with the result that the heat can be stored for a long time. The objectives are to provide cheaper heating and cooling plus a large reduction in electricity cost, achieved by cutting the need for the huge grid power generation capacity that is presently required in order to handle the large and unnecessary summer and winter demand peaks.**

Keywords—energy, exergy, storage, heating, cooling, DHW, isothermal storage, heat pump, ground heat exchanger, paraffin wax

Introduction

During the summer countries like Canada have a huge and readily accessible source of energy in the form of the heat stored in the air. That heat can be transferred into the ground using a borehole ground heat exchanger[1] but if the borehole is isolated then by the arrival of winter the heat will have migrated too far away from the borehole to be accessible for recovery. However, in the case of an urban community in which each of the properties has its own injection borehole then the heat from one borehole will only travel laterally until it encounters a similar heat flow from an adjacent property. It typically takes about six months for the spreading heat to reach the property line so over the summer to winter period of time the heat will fill the column of land within the property boundaries. If the borehole is, say, 100 m deep and the area of the property is 100 m^2 then the column of heated ground will be 10,000 m^3 in volume and by wintertime the heat will be uniformly distributed and its temperature will remain nearly static for many months.

A small amount of heat will be lost from the top and bottom of the column but heat travels so slowly in the ground that such a loss is quite small and can be compensated for by injecting a little extra heat in the summer. The cost of injecting that extra heat is very small because the injection only requires enough energy to run the circulation pump and the air-exchange fan.

By the time winter arrives the amount of heat that is accessible for extraction via the borehole amounts to the natural energy content, amounting to what would have been available from a ground source heat pump system, plus the net injected heat. On very cold days the former is difficult to extract in the case of a regular ground source heat pump system because the loop temperature will typically approach zero, but if the operator chooses to recover only the amount of heat that was injected in the summer then it is much easier to recover that part of the heat. The result is that overall such a system can inject whatever amount of heat will be needed in the winter (adjusted for the end losses) and will recover the amount needed to heat the building plus the hot water requirement (DHW). The properties around the periphery of the array will need extra heat to be injected because they cannot retain all of their injected heat.

The temperature of the recovered heat will not be much higher than the original ground temperature (about 10 degrees C in the populated areas of Canada)[2] so such systems need a heat pump to boost the exergy of the heat, typically raising it to about 42 degrees C for the building's HVAC system. Such systems work at lower temperatures than conventional "boiler" systems because the heat pumps cannot achieve enough lift to deliver higher temperatures.

Heating/cooling system design

Figure 1 shows a design for such a system that adds some useful features. It employs two isothermal storage tanks[3], one operating at zero degrees (water) and the other at 42 degrees (selected paraffin wax). The water freezes at night and then the ice melts during the day. In the summer the heat pump draws heat from the cold isothermal store at night (and/or during the day if solar power is available). The cold isothermal store extracts heat from the house air, providing air conditioning, and that heat is then injected into the ground. When necessary the injected heat can be augmented by heat withdrawn from the air to provide the required energy flow to be stored for the winter. In the winter heat is recovered from the ground store and is used to heat the hot isothermal store and in turn to heat the house.

The use of the isothermal stores achieves two purposes: to shift the grid power demand to the night time (or to the daytime solar power) and to enable either heat or cooling to regulate the house temperature during high demand periods, minimizing the size and power specification of the heat pump. Reducing the power demand makes it easier to drive the heat pump from solar panels, and operating at a fixed power makes it feasible to match the power load to the power supply capacity of the solar cells.

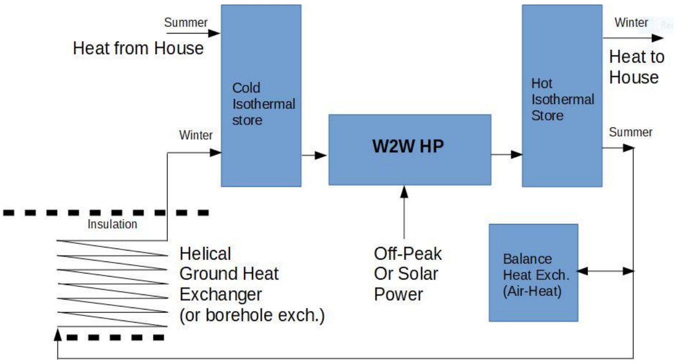

FIGURE 1

A conventional system designed to deliver 25 kW of heating may require that amount of electricity from the power grid during the peak demand periods but if the design shown in Figure 1 is employed it will not draw any grid power at all during the peak heating and cooling demand periods. Each house will therefore reduce the required national peak power capacity by that amount. In Canada the various power supply sources (nuclear, hydro or natural gas) cost from $CAD 2000 to $CAD 5000 per kW ($3,500 avg,)[4] so the grid generation cost savings could amount to $CAD 87,500 per house for just the capital cost, without considering the savings in the operating costs or the large reduction in transmission costs.

Canada has 145,000 MW of grid power capacity[5], valued at about 500 billion dollars, so if most homeowners switched to the use of stored thermal heat the national cost savings would be measured in the hundreds of billions of dollars. Note that this reduction does not come from a reduction in energy consumption but rather from a reduction in the wasteful peak power capacity requirement. Many other countries have the same problem.

Borehole layout

A few simple rules need to be followed in determining the borehole layout. First, the street volume in front of the house needs to be included as part of the storage volume. The diameter of the storage column is determined by the diameter of the property lot (if the lot is small) or by the part of the store that contributes heat during the winter (about 10m). The system does not support variances in the midwinter temperature of the storage cells – the positions of the thermal boundaries will shift to accommodate variations in the heat content. The depth of the local borehole can be adjusted to bring that cell's boundaries closer to the property lines. The midwinter temperature (and hence the storage capacity of the whole array) can be increased if more total array storage capacity is needed. For large buildings multiple storage cells can be used, with one borehole heat exchanger per cell. For residences on properties that exceed 10m in depth a second borehole heat exchanger will be needed.

Conclusion

As far as is known[6] the idea of creating an array of thermal storage cells to provide long term storage has not yet been physically employed. However, the system is made up of components that are in widespread use. The use of stored summer heat instead of using fossil fuels for heating buildings has the potential to greatly reduce the production of GHG (greenhouse gas). It also has the potential to reduce the cost of electricity by eliminating the seasonal grid demand peaks which are caused by current heating and cooling practices.

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