ACCUMULATION OF THERMAL ENERGY

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ABSTRACT

This paper deals with accumulation and storing of thermal energy, such as in phase change materials and chemical reactions, sensible thermal energy storage i.e. water tanks and underground thermal energy storage.

1. INTRODUCTION

We need energy – electrical or thermal – but in most cases not where or when it is available. Enjoying the sound of music while you are jogging, you can not stand beside the socket: electrical energy storages – batteries – make you mobile. The energy you need is stored for a short while and over the distance you like to run. Having a cold beer on a summers evening was possible even before cooling machines were invented. At that time people were cutting ice from the lakes in winter, transported the ice to the brewery and stored it in deep cellars. The cold was stored from the winter to the summer: For example for long term thermal energy storage and the utilization of renewable energies. In cold climates margin solar heat from summer can be used in winter for heating of buildings by seasonal storage.

2. ACCUMULATION OF ENERGY – THE BENEFITS OF ENERGY STORAGE

Waste heat from industrial processes, steam from solar thermal power plants or electricity from photovoltaic panels are examples for energy sources, which can not be used more extensively without energy storages. A huge potential of energy sources substituting fossil fuels can only be utilized by energy storage systems, utilizing renewables like solar thermal, photo-voltaic and wind energy. Thermal and electrical energy storage systems enable greater and more efficient use of these fluctuating energy sources by matching the energy supply with the demand. This can finally lead to a substantial energy conservation and reduction of CO_2 emissions.

The growing peak demand of today's energy consumption, essentially caused by electrical air conditioning, leads more often to black-outs all over the world. Such a problem – the shifting of a peak demand for only a few hours or minutes – can be solved by cold storage technologies. In this context energy storages can be the best solution not only from the technical point of view, but also for economical reasons [1].

3. TECHNOLOGIES OF ENERGY STORAGE

The energy to be stored can be either electrical or thermal. Both energies require completely different storage technologies. However in the actual application both technologies can meet: The peak demand of electricity for example is in most cases caused by air conditioning, which is a thermal task. The cooling demand can be covered by a cold store (ice or chilled water) which is charged at off peak hours by electric chillers.

Energy storages can be described by their storage capacity (stored energy per mass or volume), power (energy output per time), storage period (how long the energy should be stored) and size. All these parameters can vary over a huge scale: From the latent heat storage to prevent laptops from getting too hot (stored energy in the range of a few Wh) to the heat and cold thermal underground storage system (stored energy in the range of some 2 GWh).

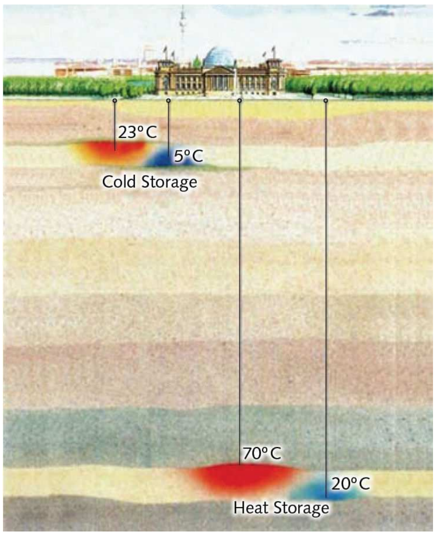

Fig.1. Heat and cold thermal underground storage system [1]

4. ENERGY STORAGE RESEARCH AND DEVELOPMENT

Many governments have committed to reduce CO_2 emissions into the atmosphere. They have decided to strengthen their national efforts and the international co-operation for research and development (R&D) in the International Energy Agency (IEA) and to increase the deployment of energy conservation technologies and utilization of renewable energy sources. So far in most industrialized countries, renewable energy sources contribute only marginally to satisfy energy demand. Energy storage technologies can help to solve problems caused by the intermittent energy supply of these sources. There is a huge potential for the application of energy storage systems. The fact that energy storage systems are not as widely used as they could, is due to several reasons, in particular because most new storage systems are not yet economically competitive with fossil fuels and their long term reliability and performance is not yet proven. There are still some regulatory and market barriers which have to be overcome. Therefore, further attempts are being made to resolve these issues. In the future more application oriented topics like thermal energy storage for cooling and industrial processes or mobile thermal storage systems for the utilization of waste heat will be investigated. The issue of implementation and deployment of new energy storage technologies has become a higher priority of the R&D [1].

5. THERMAL ENERGY STORAGE

Thermal energy can be stored in different ways given by the thermodynamics of the storage process. If a storage medium is heated up or cooled down the storage is called sensible. Well known storage technologies are hot or chilled water tanks. The phase change of the medium (e.g. ice-water) requires large amounts of energy without any temperature change; therefore it is called latent heat. These latent thermal storages can provide higher storage capacities compared to sensible heat stores at a constant discharging temperature. One example is ice storage for cooling. Energy can also be stored in reversible chemical reactions. The storage can achieve even higher capacities and is able to deliver thermal energy at different discharging temperatures dependent on the thermo-chemical reaction. An extensively studied reaction for thermal energy storage is the adsorption of water vapour on microporous materials e.g. Zeolites and Silicagel. The microporous adsorbers have a huge inner surface and can adsorb large amounts of water [1].

5.1 Thermal energy storage in water tanks and underground TES

The use of hot water tanks is one of the best known thermal energy storage (TES) technologies. The hot water tank serves the purpose of energy saving when e.g. applied to a solar tap water system and an energy supply system with cogeneration. One major aim of an electrically heated hot water tank in a tap water system is to shave the peak in electricity demand. Further R&D efforts are devoted to reduce the specific storage costs which at present are still too high for many applications of energy conservation and utilization of solar energy.

The most frequently used storage technology of heat and cold is underground thermal energy storage (UTES). The aquifer Thermal Energy Storage (ATES) uses natural water saturated and permeable underground layer as a storage medium. The transfer of thermal energy is realized by extracting groundwater from the aquifer and by re-injecting it at the modified temperature level at a separate well nearby. Low temperature heating and high temperature cooling with groundwater fits very well with new concepts of large surface area heating and cooling in walls and at the ceilings (so called low energy heating and cooling systems). Most applications are about the storage of winter cold to be used for the cooling of large office buildings and industrial processes. It can easily be explained that aquifer cold storage is gaining more and more interest: Savings on electricity bills for coolers are approx. 75 %, and in many cases, the payback time for additional investments is shorter than five years. A major condition for the application of this technology is the availability of a suitable geologic formation.

Other technologies for underground thermal energy storage are borehole storage, cavern storage and pit storage. Which of these technologies is selected, strongly depends on the local (hydro)-geologic site conditions. With borehole storage, vertical heat exchangers are inserted into the underground, which ensure the transfer of thermal energy towards and from the ground (clay, sand, rock, etc.). Many projects are about the storage of solar heat in summer for space heating of houses or offices. Ground heat exchangers are also frequently used in combination with geothermal heat pumps, where the ground heat exchanger extracts low-temperature heat from the soil [1].

5.2 Phase change materials and chemical reactions

Sensible heat energy storage has the advantage of being relatively cheap but the energy density is low and there is a variable discharging temperature. To overcome those disadvantages phase change materials (PCM's) could be used for thermal energy storage. The phase change could be a solid/liquid or a liquid/gas process. Melting processes have energy densities in the order of 100 kWh/m^3, e.g. ice, compared to 50 kWh/m^3 for sensible heat storage of a temperature change of 50 °C, which is common of hot water stores.

The incorporation of micro-encapsulated PCM materials such as paraffin wax into the gypsum walls or plaster increases considerably the thermal mass and capacity of lightweight buildings. By night the PCM in the microcapsules cools and solidifies. During the day the cool walls, reducing the daily temperature swing by several degrees, and thereby avoiding the need for electric chillers or, at a minimum, reducing the cooling requirements. Another application of active cooling systems is macro-encapsulated salts that melt at an appropriate temperature.

Higher energy densities can be achieved by the utilization of chemical reactions for thermal energy storage. Energy densities in the order of 300 kWh/m^3 are possible. Thermochemical reactions like adsorption (the adhesion of a substance to the surface of another solid or liquid) of water vapor to Silicagel or Zeolites (micro-porous crystalline alumo-silicates) can be used to generate heat and cold as well as to regulate humidity. Of special importance in hot, humid climates or confined spaces where humidity levels are high, these open sorption systems use lithium chloride to cool water and Zeolites to absorb ambient humidity.

The researchers have found a way to integrate the temperature-equalizing effect of thick walls within a millimeters-thin layer of plaster. The secret is that the material contains micro-encapsulated paraffin. This wax-like additive stores heat and greatly improves the thermal capacity of decorative plaster and dry-wall construction panels. Thanks to the tiny wax-filled balls, a mere six-millimeter thick facing can store just as much heat as a massive brick wall. This enables lightweight walls to provide just as much thermal comfort as a solid wall. The researchers developed the new material by taking advantage of the special characteristics of paraffin. When the long-chain hydrocarbons heat up, the temperature of the paraffin barely increases at first. The energy is required to break down the bonds between the wax molecules. The heat is stored as latent heat. When the paraffin returns to its solid state, the latent heat absorbed during the day is released again. These materials that use thermal energy to change their state, for instance from solid to liquid, are described as phase change materials [2].

Fig.2. Paraffin and wax based phase change materials RUBITHERM® RT [3]

6. CONCLUSIONS

The different technologies for thermal energy storage can be used in a huge variety of applications. Domestic hot water, space heating and cooling are probably the most common ones. Most of the sensible thermal energy storage systems are operated for that purpose. Heat storage technologies enable the utilization of summer solar heat for winter heating. With compact heat stores, micro cogeneration technologies (e.g. fuel cells) can be operated more efficiently, following the electricity demand at every moment. In short, every device that needs heat to supply its service can be used more effectively when it is equipped with a compact and efficient heat storage technology.

7. REFERENCES

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This work was supported by Scientific Grant Agency of the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences under the project VEGA No. 1/3141/06.

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