Hybrid heat pumps under the spotlight

In a series of articles Metkel Yebiyo and Graeme Maidment of SIRACH are reviewing individual heating and cooling technologies on a bi-monthly basis. We describe the technology, its principle of operation, main applications, the challenges and opportunities in penetrating market and what's needed for that to happen. This month we will describe the hybrid heat pump.

Basic working principles

In households not connected to mains gas, electric heat pumps offer the opportunity to provide high efficiency low carbon heating as an alternative to electric heaters, LPG or oil based systems. As a result this technology is an ideal heating solution for the 4 million households in the UK that don't have access to mains gas. However, electric heat pumps also offer large scale carbon savings when used for heating in the 22 million households that do have gas as well as mains electricity. In these applications hybrid heat pumps present an attractive opportunity for reducing fossil fuel consumption. In March 2013, the Department for Energy and Climate Change (DECC) published a document entitled "The Future of Heating: Meeting the challenge". This report predicted that by 2030 approximately 26% of the UK's heating energy output will be met by air source heat pumps alone, and as much as 56% will be met by hybrid systems. A schematic of a hybrid heat pump with a condenser and gas boiler connected in parallel is shown in Figure 1 below.

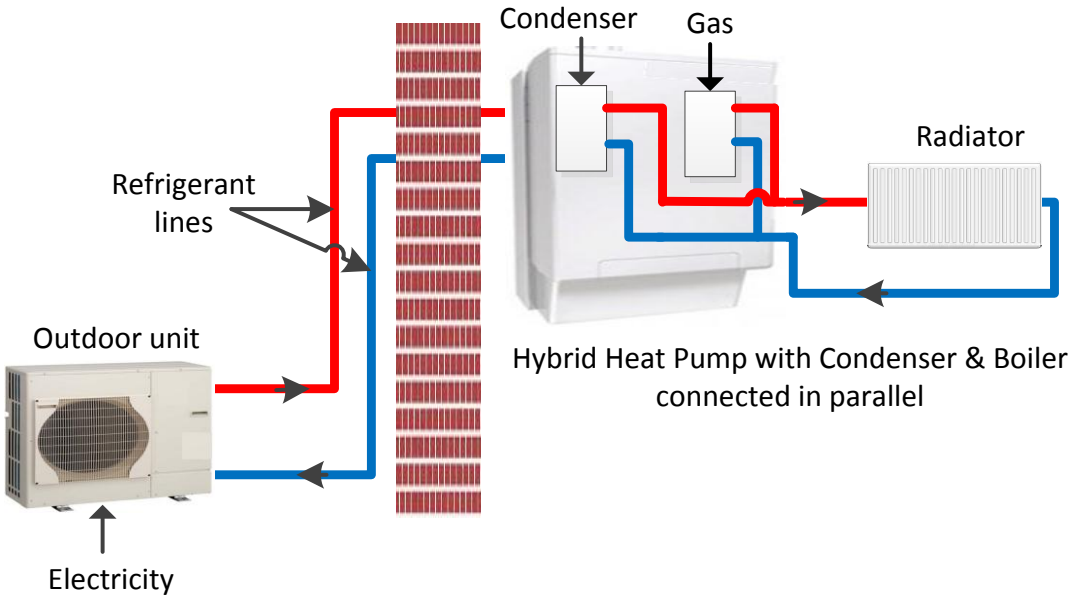

Figure 1 Schematic showing basic working principle of hybrid heat pump

Hybrid heat pumps consist of a unique combination of a high efficiency gas boiler combined with an air to water heat pump. Hybrid systems are defined as those systems which provide heating, cooling and/or domestic hot water through the combination of two or more energy sources to form a single system, thereby overcoming the limitations of the individual technologies. Operation modes vary according to different manufacturer's control strategies. The heat pump can be used to cover most of the annual heating demand and only needs to be supplemented by the boiler during periods of low ambient temperature in winter, or to cover peaks in demand. In such an installation, the boiler and the heat pump can either run in combination or in isolation. This hybrid operation mode has been suggested to increase energy efficiency by approximately 10%, compared with a condensing gas boiler alone, and can minimise running costs by dynamically switching between the systems in

response to variable outdoor temperatures or to varying electricity and gas tariffs. However their main advantage of hybrid operation is that it minimises potential pressure on the electrical distribution grid associated with switching from boilers to heat pumps during periods of high heat demand. This can be seen in Figure 2 which shows the UK hourly demand for heat and electricity in 2010. This shows the design point for heat delivery and the peak electricity demand assuming conventional heat pumps are used. This is significantly greater than the current electrical delivery point. Hybrid heat pumps are one way of overcoming this limitation, since gas boilers can be used to deliver part of the heat requirement during periods of peak demand.

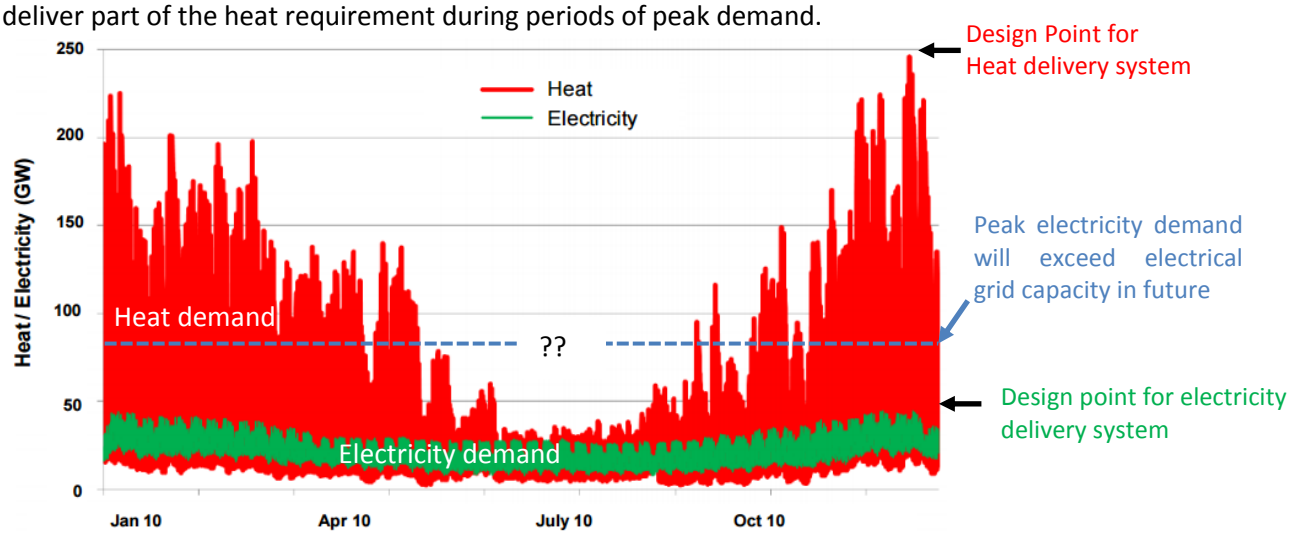

Figure 2 UK hourly demand variability for heat & electricity in 2010
(Source: i-Stute Breakfast Forum presentation by Sugden, L)

Potential applications & current market development

Hybrid systems have potential for use in small-scale applications like heating and hot water systems for residential applications as well as in large-scale applications such as for district heating and hot water or in industrial processes.

A study by Delta-ee, on the market development and outlook for hybrid heat pumps, indicated that hybrid systems with gas boilers have greater potential for application in markets such as the UK, the Netherlands and Germany. With regards to the residential heating sector, it should be borne in mind that traditional fossil fuel based solutions are generally characterised by low initial costs for the equipment and installation. Hybrid heat pump based solutions must therefore be optimised to achieve a competitive total cost of ownership in order to successfully penetrate this market. Research, development and demonstration activities that demonstrates a reduction in the total cost of ownership will support the market penetration of hybrid heat pumps.

The marketing study by Delta-ee also shared that four of the five biggest gas boiler manufacturers in Europe are already offering a range of new products of with 20 different hybrid heat pumps on the market. Some of the companies providing this technology include Bosch, Daikin, BDR Thermea, Viessmann, Vaillant or Ariston, Mitsubishi electric, Atlantic and Glow-worm.

Benefits of hybrid heat pumps

There are significant benefits from using hybrid heat pumps, as compared to traditional gas boilers and a conventional heat pumps, these include:

- The potential to significantly reduce CO_2 emissions e.g. by up to 1.5 tonnes/year for domestic applications thereby offering a more sustainable heating solution in comparison to conventional systems.
- By selectively switching between different energy fuels a hybrid heat pump can be configured to always deliver either the lowest cost of heating or the lowest CO_2 emissions based upon knowledge of a combination of fuel tariffs, heat pump coefficient of performance (COP) and boiler efficiency.
- A key marketing advantage of heat pumps is that they are eligible for the Government's renewable heat incentives (RHI) scheme which provides subsidy back to the user of 7.42 p/kWh heat generated. For a typical size house this could provide an annual return of around £2700/year.

Challenges

Although this technology is commercially available, a number of challenges still remain. These include:

- Efforts need to be put into developing compact / prefabricated hybrid systems capable of fitting within the existing envelope of the range of conventional boilers.
- Specific research efforts are needed in order to develop integration kits enabling the installer to easily and quickly integrate the new technology into existing systems.
- As hybridisation implies interaction between complementary technologies, research focusing on the development of advanced algorithms for control and automation strategies is a top priority if hybrid systems are to reach their full potential. Smart systems that are able to intelligently select the fuel or hybrid mode based on pricing and or COP/ efficiency data are needed.
- One major challenge of hybrid systems is to maximise the combined efficiency of the technologies while at the same time minimising both the operating cost and the environmental impact.
- Opportunities exist to link with renewable energy technologies however, these may require energy storage. This would provide improved performance/cost ratio.
- In parallel with system development, new standards also need to be developed.
- A downside of the hybrid heat pumps is that they use a refrigeration cycle and there is therefore potential for refrigerant leakage.

Verdict

Hybrid heat pumps have been installed and tested at a range of different field sites, in various climates and house types and with different heat emitters. The technology has significant potential to reduce energy use and carbon emissions.

To find out more about heating and cooling technology please come to one of the regular SIRACH meetings held throughout the country at leading universities and at businesses who engage in research in this area. On the 23rd November 2016 the SIRACH network will be visiting the International Energy Research Centre (IERC) in Cork. The IERC is an industry led, world-leading organisation, collaborative programmes in research and innovation into integrated sustainable energy system technologies that will have significant impacts in terms of reducing CO_2 emissions, both in the long and short term strategy towards the UK target of an 80% reduction in carbon

emissions by 2050. **For more information or to be included on the SIRACH mailing list please register at www.sirach.org.uk or email info@sirach.org.uk**