Zukunft Bau

SUMMARY

Title

Development and investigation of new control strategies for assisted compression heat pump plants with a geothermal probe for heating and cooling considering seasonal influences

Occasion

The performance coefficient of heat pumps depends on the temperature difference between heat source and destination. They vary seasonally and depend on the usage. Hence, temporarily unfavourable operating conditions for the heat pump can occur and reduce the overall efficiency of the generating plant, whereas the second generation unit still has enough power reserves. They often remain undetected and are not considered in the plant control systems.

Content

The project presents an approach for the control of an assisted heat pump plant. Herewith, different properties of the generating units should be used, and the approach represents an efficient alternative to the traditional baseload use of heat pumps.

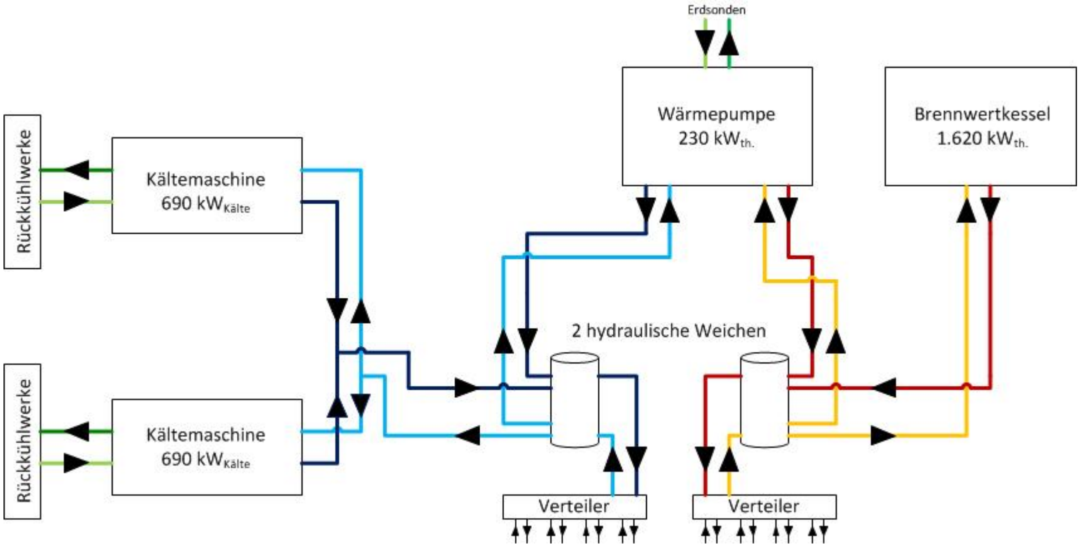

Figure 1: Composition of the plant

The project aims to optimize the assisted heat pump usage. Periods of uneconomic operation (low coefficient of performance) should be automatically detected in order to switch to a favourable generating unit and to achieve a better overall efficiency of the generating plant throughout the year. The assessment of the generating plants can be carried out with respect to economical and ecological aspects, and various factors can be taken into account. The performed analyses consider prices and carbon emission levels of primary energy. Capital or operating costs, or their carbon emissions respectively, could also be taken into account.

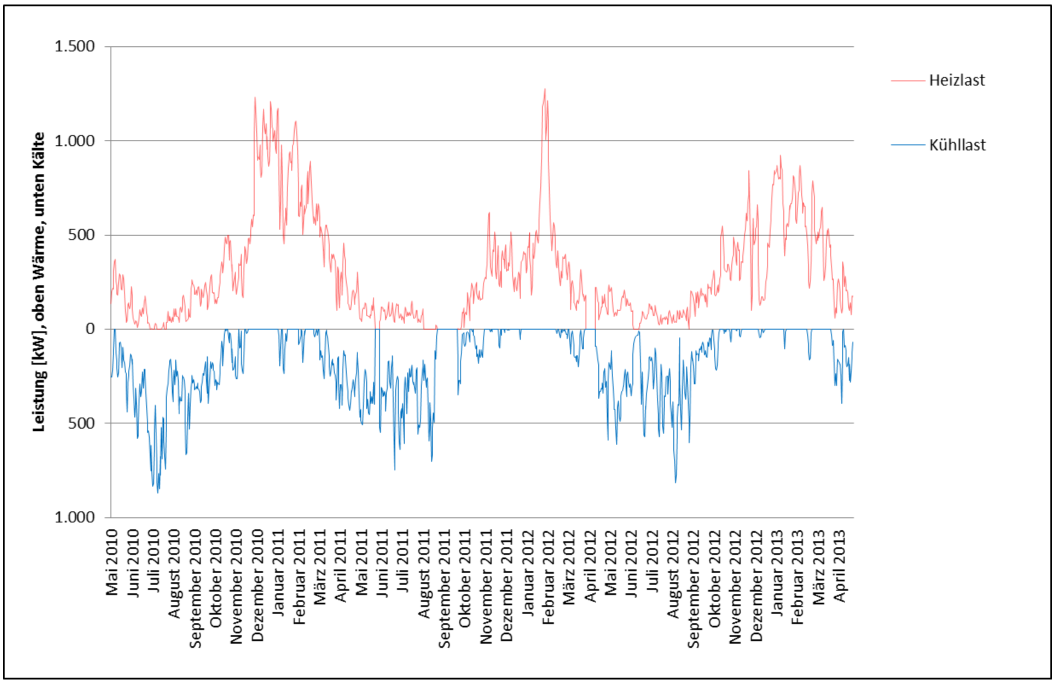

Figure 2: Load profile

The analyses were performed by using a validated simulation model, representing the portion of a real generating plant and considering the composition of the plant (cf. fig. 1), associated characteristic curves of the generating units, and the real behaviour descriptive control. The load profile (cf. fig. 2) with the corresponding temperature curve (cf. fig. 3) is added for a period of three years. The differences between real data and simulation data, including flow temperatures, generating power, and the distribution to the different generators, indicate a realistic behaviour of the validated simulation model. A basic version, based on the simulation model, is created due to privacy protection. For the purpose of anonymity, the characteristic curves of the generating units are primarily replaced. Nevertheless, this basic version is similar enough to the real generating plant.

In the simulation model, the generating units are switched on via a PI controller, which compares the flow temperature of the heating or cooling cycle with the desired value from the load profile. With increasing controller output, the model element of the heat pump is switched on first before the corresponding conventional generating unit is activated if the system states are in the respective operating range.

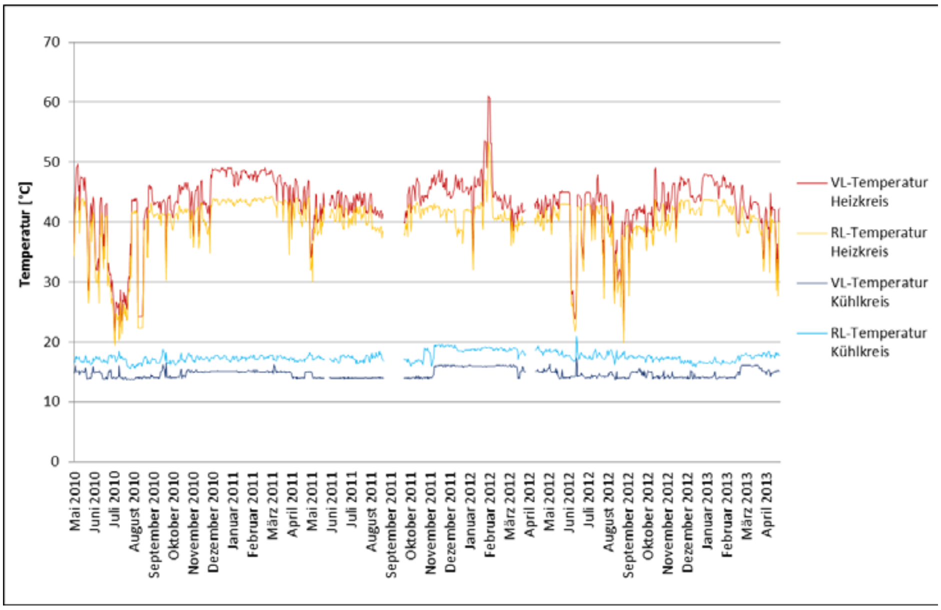

Figure 3: Temperature curve

The control can be optimized either for an economical or ecological operation. For this purpose, carbon emission levels and energy prices have been stored and the expected efficiencies of all generating units are calculated from the characteristic curves at any time. If the model element of the heat pump causes higher carbon emissions or energy costs than the corresponding conventional generating unit, the base-load use of heat pumps will be locked (cf. fig. 4). The simulation model is calculated with a classical, economical and ecological control version. The simulation result data, in particular the system temperatures at the model elements of the generating units and their power, primary energy consumption, the coefficient of performance and the control quality of flow temperatures were directly compared to the three control versions.

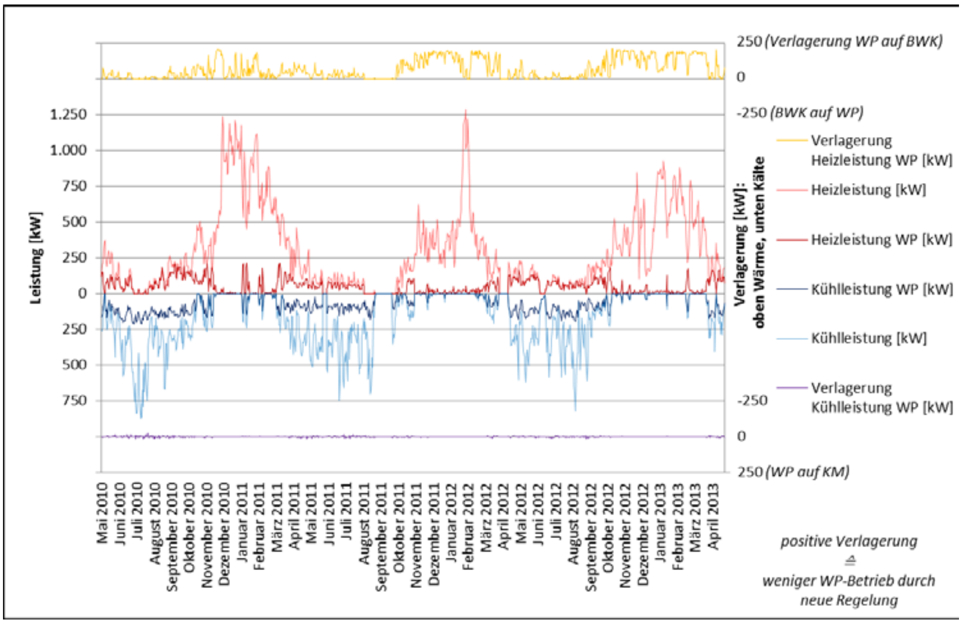

Figure 4: Shifting of power in the basic version with the economic control

Starting from the basic version of the simulation model, a parameter study has been conducted, where the influences of important parameters on the results could be evaluated and limits of applications of the approach could be defined. Under the assumed conditions (especially regarding composition of the plant, characteristics of the generating units, control system and load profile), different results were obtained in the parameter study. Based on acceptable heat pump operating times using the classical control variant, 5% to 8% savings could be found through economic optimizations, even if different parameterization of system temperatures, heat source and heat pump characteristic curves were applied. Altered energy prices resulted through the economic optimization savings between 0.5 % and 14 %. Significant carbon emissions savings couldn't be achieved in any parameter variation (cf. fig. 5). A higher heat pump operating time would increase the carbon emissions savings, which is not possible because it leads to the maximum operating time of the heat pump. Hence, the base-load use is already optimal from an ecological point of view for the plant.

Modellvariante		Veränderung	CO_2-Ausstoß [t]		Gesamtenergiekosten [€]	
			monetär	ökologisch	monetär	ökologisch
A		Basisvariante	-2,2 %	+0,1 %	+6,1 %	+0,1 %
B	1	Temperaturen HK - 10 K	-5,6 %		+4,8 %	
	2	Temperaturen HK - 5 K	-4,1 %		+6,4 %	
	3	Temperaturen HK + 5 K	-0,5 %	+0,1 %	+1,1 %	+0,1 %
	4	Temperaturen HK + 10 K	+0,1 %	+0,2 %	+0,4 %	+0,2 %
C	1	Sole-RL fix 10 °C	-3,0 %		+5,7 %	
	2	Soletemperaturen + 5 K	-3,6 %		+5,2 %	
	3	Soletemperaturen - 5 K	-1,1 %		+6,4 %	
	4	geringere Speicherkapazität Erdreich	-1,8 %		+6,2 %	
	5	höhere Speicherkapazität Erdreich	-2,5 %		+5,9 %	
D	1	Wärmepumpenkennlinie WP-II	-0,6 %		+7,6 %	
	2	Nebenstromverbrauch der WP-I erhöht	-0,7 %	+0,1 %	+7,7 %	+0,2 %
	3	WP-I Heizkennlinie + 10 %	-3,7 %		+5,0 %	
	4	WP-I Heizkennlinie - 10 %	-0,6 %		+7,1 %	+0,1 %
E	1	Energiepreise 3 Jahre später	-2,1 %	+0,1 %	+4,8 %	+0,1 %
	2	Strom teurer, weniger Emissionen; Gas billiger	-10,3 %		+13,9 %	
	3	Strom günstiger, noch weniger Emissionen	-5,9 %		+0,5 %	

Figure 5: Summary of results

Conclusion

The results show considerable efficiency gains using the economic control variant for the assumed conditions but resulting only in low carbon emission savings. The decisive factor is the implementation effort for such a control approach, in particular in different combinations of generating units and hydraulic circuits of large plants. The future development of the energy market has a great influence. Here, energy prices, the energy mix (and thus carbon emission level), and distribution systems (in particular tariff structure) play an important role, and fluctuations can lead to a very positive effect with respect to the control approach (also with regard to carbon emissions).

Key data

A control strategy for an economical operation of assisted heat pump

Research group:

RWTH Aachen University
Chair of Construction Business and Building Services
Institut of Energy Efficient Building
Researcher:
Dipl.-Ing. Dipl.-Wirt.Ing. Georg Form

Project manager:
Univ.-Prof. Dr.-Ing. Marten F. Brunk
Univ.-Prof. Dr.-Ing. habil. Christoph van Treeck

Total costs: 328.626 €

Quota state grant: 189.426 €

Project duration: 21-09-2011 to 31-12-2014