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DATA CENTERS AND ENERGY SYSTEMS: AN ON-SITE INTEGRATION

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SUMMARY

Data centers today consume between 2% and 4% of the electricity worldwide. Small data centers are responsible for half of this consumption. Data centers continue to expand rapidly and this presents a threat to their sustainable operation. Aquifer Thermal Energy Storage (ATES) is one of the promising technologies for cooling of data centers. ATES consists of two boreholes, which serve as cold and hot storage.

One of our case studies in Denmark recently installed the ATES storage. During summertime, cold is extracted from the ground to provide cooling for data centers, while in winter it's recharged with free coolers that can operate when the temperature outside falls below 8 $_{o}$C. However, as a consequence of the climate change, summers are becoming hotter, and winters are becoming milder, creating an imbalance in the projected operation. In order to improve the operation of the ATES, an on site integration of heating and cooling systems is proposed. A mixed integer optimization model was developed for on site integration of heating and cooling systems. The model takes into account operational constraints of the system and also serves as a capacity expansion model. The results showed that two heat pumps, using ATES hot storage as a heating source, should be installed, with capacities of 200 kW and 240 kW, respectively. The payback period was calculated to be 6.51 years, while the internal rate of return was 13%. Gas consumption for district heating dropped by 76% and CO2 emissions reduced by 49.6%. The results showed that there are still low-hanging fruits regarding the data center energy efficiency. However, data centers need to be fully integrated to the energy systems.

Keywords: Data centres, integrated energy system, local energy system, aquifer thermal energy storage

BACKGROUND

Globally, the electricity demand generated by DCs has been estimated at around 194 TWh, corresponding roughly to 1% of global final demand for electricity in 2014 [1]. This demand is expected to double every five years due to increasing digitalization [1]. The electricity consumed in DCs is almost completely converted into low temperature heat [2,3], while 98% of the waste heat for cooling can be recovered and used e.g. for district heating [4].

Denmark can expect larger growth rate than the average development of DCs [5]. Danish experts forecast that total electricity demand from DCs by 2030 could be up to 30% of the Danish 2017 electricity consumption [6]. If no actions are taken, this demand could increase by 13.8 TWh by 2050, a 42% rise compared to 2017 electricity consumption in Denmark [1].

METHODS

A linear mixed-integer model was developed in order to calculate the feasibility of the investment. The algorithm seeks to minimize the yearly cost of the energy system, taking into account the capacities of currently installed equipment, as well as the possibility to invest in new heat pumps. Heat pumps were modelled to use ATES as a heat source and thus. Costs included fuel costs, such as gas for district heating and electricity, as well as the potential annualized capital cost associated with the investment in a heat pump. Annualized capital costs presents the annuity that needs to be paid back for the loan used to cover the cost of the heat pump investment. Interest rate of 5% and loan duration of 15 years was assumed in the calculation. Hence, the potential capital expense is competing only against the potential savings between the current system and the upgraded one.

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RESULTS

From the economic standpoint, the optimization algorithm showed that yearly savings of 212,960 DKK can be achieved by upgrading the system with heat pumps, taking also into account larger CAPEX due to capitally intensive investment in a heat pump. Total system cost for cooling and heating systems would drop by 17.2% (from 1.44 MDKK to 1.19 MDKK). Gas consumption in district heating would drop by 72.8% and CO2 reduction would reach a significant 49.6%. Electricity consumption would increase from 346.7 MWh to 847.3 MWh.

One should notice another environmental benefit here. In the new system, most of the heating and cooling demand would be met by electrically driven equipment. In line with the general reduction in carbon intensity of the Danish power grid, CO2 reduction would increase every year.

Optimization algorithm was run for both the current situation (without installed heat pumps) and for the new system. The results showed that it would be optimal to install two heat pumps with the capacity of 200 kW and 240 kW, for two independent energy system blocks.

Following the results of the optimization algorithm, a chosen heat pump with its cost and capacity, as well as data on electricity consumption and gas savings from optimization algorithm, was extracted and used as an input for the feasibility study.

Following inputs were further used in the project feasibility calculation: interest rate of 5%, project lifetime of 15 years, COP value of 2.96, fixed operating and maintenance (O&M) costs of 2% of the investment per year, variable O&M costs of 9 DKK/MWh of heat, and a corporate tax rate of 22%. 65

As KPIs, net present value (NPV), simple payback period and internal rate of return (IRR) were calculated.

CONCLUSIONS

All the main economic indicators showed that it would be beneficial to invest in heat pumps, in order to fully utilize already existing equipment. Furthermore, the used approach showed that integrated modelling of both heat and cooling system brought significant synergies and better utilization of the already existing equipment.

The biggest enabler for the proposed change was a regulatory change from the beginning of this year that removed the heavy taxes imposed on the use of waste heat.

In addition to the economic benefits, the proposed changes would reduce CO2 emissions by 49.6% with the tendency for even larger reduction as the national power grid becomes greener.

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