DEVELOPMENT OF OPTIMAL OPERATION OF THERMAL STORAGE TANK AND THE VALIDATION BY SIMULATION TOOL

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ABSTRACT

Optimization of thermal storage tank operation is one of the major areas for energy conservation in HVAC systems. In the present paper, an algorithm is developed for optimum operation of thermal storage tank, by minimizing non-linear cost function. Results are validated under stationary and random load conditions. It is concluded that the present algorithm is quite robust and provides an optimal scheme of operation.

INTRODUCTION

To meet the national requirement of 6% reduction in CO2 emission made at the COP3 Kyoto in 1997, thermal storage used for air-conditioning systems was designated one of the major CO_2 reduction means in building sectors by the Japanese government. Thermal storage tank are widely used in Japan and elsewhere to store energy at off-peak hours, thereby flattening the electricity demand and increasing the chiller COP when outside wet bulb temperature is lower than day time. However, the statistics show buildings with such systems consume more energy as compared to these without it. One of the main reasons of this problem is that air-conditioning system operators try to store maximum thermal energy at the lowest temperature level to avoid shortage on the following day. Therefore, computerized optimal operation using predicted future thermal load profile of a following day might be a powerful tool because optimal operation of the system is very complicated and beyond human experience[3],[4],[8].

The three most important factors influencing electric power consumption by an HVAC system with thermal storage tank are,

1) The operating time of the chiller: Ordinarily the operating time of the chiller is not controlled and the thermal storage tank is filled with heat without any limit. Therefore, water temperature in the tank remains low and consequently the chiller COP goes down and higher heat transfer loss from the thermal storage tank takes place.

2) The operating schedule of chiller: When the chiller operates at midnight, the water temperature in the thermal storage tank remains low after completing the heat storage operation till its use. So the heat transfer loss from the thermal storage tank becomes larger than that when the chiller operating schedule shifts to early morning. In this shifted operation, the chiller can be operated at high COP taking advantage of the morning outside low wet bulb temperature .

3) The chilled water temperature: Energy consumption in the chiller can be saved by setting the evaporator outlet water temperature as high as possible because of the improvement of the chiller COP. When the following day thermal load is not so large, too low chilled water is needless. On the other hand, if the chilled water temperature is above a fixed temperature, it cannot handle the load satisfactorily.

In the present paper, authors propose an optimal operation scheme which was developed as computerized software on MATLAB/SIMULINK environment and results are obtained using operational data of a real building. Optimization is achieved by determining optimal chiller outlet water temperature taking account the performance of storage tanks, chiller, cooling tower, pumps and AHU coil. The optimum operation is determined by minimizing non-linear cost function together with simulation of the models. Four cases of operation are considered (Table 1).

OPTIMAL OPERATION ALGORITHM

The optimal operation algorithms for HVAC systems with a thermal storage tank are made up of four blocks (Fig. 1), prediction of cooling load, determination of required heat storage, system simulation, and optimal system operation control. The first block predicts cooling load for the following day. The second block determines heat storage requirement on the basis of cooling load prediction. The third block comprises quasi-stationary model in which components are expressed as numerical expressions. By using this model power consumption of the following day at the

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