Optimal control design for a solar greenhouse

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1 Introduction

The research of my Ph.D.-thesis was part of a larger project aiming at the design of a greenhouse and an associated climate control that achieves optimal crop production with sustainable instead of fossil energy. This so called solar greenhouse design extends a conventional greenhouse with an improved roof cover, ventilation with heat recovery, a heat pump, a heat exchanger and an aquifer. The thesis describes the design of an optimal control strategy for the solar greenhouse, to ensure that the beneŒts of this innovative greenhouse are exploited in the best possible way.

The ingredients of an optimal control design are a dynamic model for greenhouse and crop, an explicitly formulated cost function, and a solution method. The advantages of this systematic approach are that scientiŒc knowledge concerning the greenhouse and the crop is fully exploited, and with a goal that is stated in clear and transparent quantitative terms, it computes the best possible control. Furthermore it gives œexibility because the control is automatically adjusted when economic or other factors determining the cost function are changed. The control objectives used here are: minimize gas use and maximize crop yield, development and quality. Since the optimal control fully relies on the cost function and the dynamic model, this model must give a good description of the system response for a wide range of temperature and humidity conditions.

2 Contribution

The Œrst major contribution of the thesis is the development of a comprehensive, science-based, dynamic model of the greenhouse-with-crop system in a form that is suitable for optimal control purposes. The model describes the temperature, the carbondioxide balance and the water vapour balance in the greenhouse, as a function of the external inputs (i.e. the outdoor weather conditions) and the control inputs (e.g. valve positions and window apertures). This model has been validated with data, and was found to give a good description of reality.

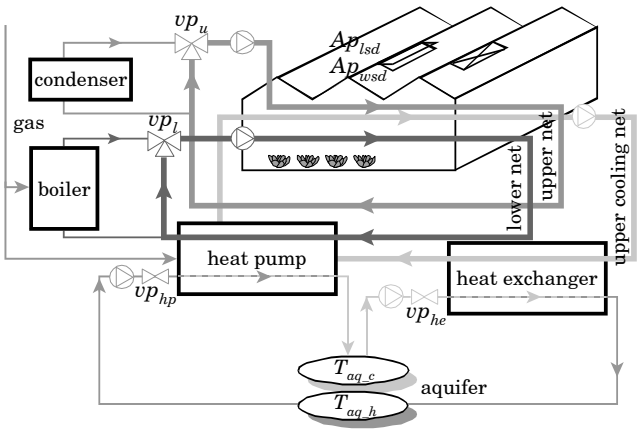

Figure 1: Greenhouse conŒguration

The second major contribution of the thesis is the design of the optimal controller, including an efŒcient solution technique. A conjugate gradient search is used as the ultimate Œne-tuning method, but it has the risk of achieving local minima, and it is time consuming. Therefore, a grid search method has been designed to provide a good initial guess for the gradient search method. This method uses only a small number of discrete constant control trajectories, which are then modiŒed with rule based state dependent control input bounds to obtain initial control trajectories.

3 Results

Receding horizon optimal control has been used for year-round computations of the solar greenhouse with crop. Extensive analyses have been made of the effect of various components of the solar greenhouse system and of the uncertainty in weather. Growers should be aware that setting tighter humidity bounds increases energy use. It was found that in the optimally controlled solar greenhouse, gas use can be seriously reduced (by 52%), while the crop production is signiŒcantly increased (by 39%), as compared to an optimally controlled conventional greenhouse without the solar greenhouse elements.

References

R.J.C. van Ooteghem (2007). *Optimal control design for a solar greenhouse* Ph.D. thesis, Wageningen University, Wageningen, The Netherlands. 304 p.