APPLICATION OF THE RECEEDING HORIZON METHOD FOR STEAM GENERATOR WATER LEVEL CONTROL

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This paper presents an application of advanced control methods to a typical steam generator. This research is part of a NERI project in cooperation between the US Department of Energy and the Korean Ministry of Science and Technology. The overall NERI project focuses on the development of methods for automated generation of control systems that can be traced directly to the design requirements for the life of the plant.[1-2] The technique used in this application is the receding horizon control methodology, which has received much attention as a powerful tool for the control of industrial process systems.[3-4]

The basic concept of the receding horizon control is to solve an optimization problem for a finite future at current time and to implement the first optimal control input as the current control input. As it were, at the present time k, the present and future control inputs on the control horizon M, $u(k), u(k+1), \cdots, u(k+M-1)$, and the predicted outputs over the prediction horizon N, $y(k+1), y(k+2), \cdots, y(k+N)$, are obtained by solving an optimization problem represented by a specified objective function. Among these solutions, only the first computed change in the controlled variable, $u(k)$, is implemented for time $[k, k+1]$. The procedure is then repeated at each subsequent instant. This method presents many advantages over the conventional infinite horizon control because it is possible to handle input and state (or output) constraints in a systematic manner during the design and implementation of the control. In particular, it is a suitable control strategy for time varying systems. Therefore, in this work, the receding horizon control method was used to solve the steam generator water level control problems.

The associated performance index for designing the controller can be written as the following quadratic function:

$$J = \frac{1}{2}\sum_{j=0}^{N-1}\left(Q\left[L(k+j) - L_{set}(k+j)\right]^2 + \mu\left[\Delta u_{uv}(k+j)\right]^2\right) + \frac{1}{2}Q_F\left[L(k+N) - L_{set}(k+N)\right]^2$$

where L is the model-predicted water level, L_{set} is the time-dependent level setpoint, and Δu_{uv} is the mismatch between feed and steam flows. Q, Q_F, and μ are positive-defined weighting factors, and $\Delta u_{uv}(k+M) = \cdots = \Delta u_{uv}(k+N) = 0$. The level control is accomplished by modulating the feedwater flow according to the sequence *u(k)* that minimizes the above performance index, J. To this end, the above equation is minimized at each time step using a reference model to predict *L(k)* in the near future.

The proposed controller was implemented using a linearized model of a nuclear steam generator to generate the predicted level sequence, *L(k).* Then the controller was applied to three different steam generator models to verify its performance. Two of the models were linear, and one was a non-linear model. In addition, the model parameters were changed slightly to simulate real life, where the plant parameters are not exactly known. Note that the parameters of the linear models for a steam generator are very different according to the power levels. However, although the receding horizon controller was designed by using the linear steam generator model fixed over a certain power range, the proposed controller showed good performance for any other power level within the power range.

Figure 1 shows an comparison between the receding horizon controller and an optimized PI controller when they are applied to one of the above linear steam generator models at a steady state power of 5%, which is a non-trivial control problem. The proposed controller also showed good performance for the water level setpoint tracking and steam flow rate (measurable disturbance) changes using the nonlinear model.

In summary, this paper shows a successful implementation of an advanced control methodology for steam-generator level control. The proposed methodology has been shown to result in more accurate and responsive control than conventional controllers, even if the plant dynamics are not perfectly represented by the reference model.

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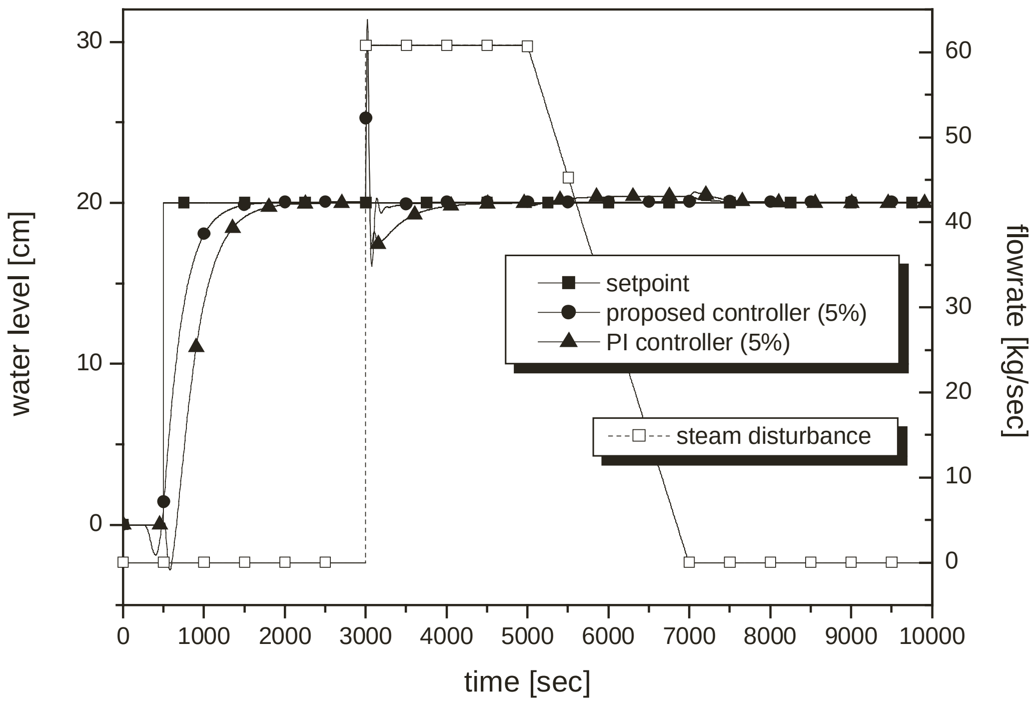

Fig. 1. Performance of the receding horizon controller and an optimized P-I controller.