According to the U.S. Energy Information Administration (EIA), the net worldwide power generation is expected to experience an annual increase of 2.2% until the year 2040 with coal remaining the main fuel used [1]. However, due to the increased awareness of the negative impact of fossil fuels emissions to the environment, and due to governmental policies and incentives, the use of renewable fuel sources for power generation, mainly wind power and hydropower, is expected to increase at an annual rate of 2.8% resulting in producing 25% of worldwide power by 2040 as indicated by [1]. The integration of renewable power into the grid imposes several challenges in the operation of existing fossil fueled power plants. For example, due to the intermittent nature of renewable power sources the power demand required from fossil fueled power plants is continuously changing to meet the power demand of the region these facilities are serving. This challenge can be addressed by designing a control strategy for conventional power plants to accommodate a broad range of variations in power demand.

Power generation has two main complications that may restrict the effectiveness of a control strategy. First, there exist strong nonlinear interactions between the different components of the plant, specifically between the steam turbine and the boiler. Second, in plants utilizing solid fuels, there is a deadtime that accompanies the fuel supply to the process when boiler pressure adjustment is necessary. Previous studies have have proposed coordinated control strategies (CCS) utilizing PID controllers to lessen the nonlinear interactions and deadtime effect, whereas other studies targeted eliminating the deadtime by implementing model predictive control based on a linear model for the plant. Although the results achieved are promising, these control strategies are only efficient over a narrow operational range due to the linear models and controllers used. Nonlinear empirical models derived from actual operating data have been utilized in some studies. The disadvantage of using such models is the inability to generalize the control schemes derived to serve any power plant in general.

The purpose of this presentation is to present a controller design that accounts directly for the effect of nonlinearity and of the deadtime in the system. We propose a nonlinear controller that utilizes nonlinear decoupling state feedback combined with deadtime compensation scheme similar to the one in [2]. Our objective is a control scheme that provides stable closed-loop performance and efficient multi-range setpoint tracking. To this end, a dynamic nonlinear model for the pressure in the boiler and for power generation by the turbine-generator system is utilized. The control problem is identified for an 80 MW coal-fired power plant that utilizes a constant-pressure operating boiler, with the fuel flow to the boiler and steam flow to the turbine as manipulated variables, and with boiler pressure and power generation as state variables. The deadtime appears only in the fuel flow rate. Narrow and wide operational ranges of set point tracking were selected to test the performance of the proposed controller. For further performance analysis, nonlinear decoupling controller without deadtime compensation and a linear MIMO controller composed of a PI

controller and a Generalized Multidelay Compensator (GMDC) [3] were also studied and compared.

The results for the proposed nonlinear deadtime compensated controller show complete decoupling of the boiler pressure and power generated with faster and more stable performance compared to the performance of both the uncompensated nonlinear controller and the PI-GMDC.

References

[1] *International Energy Outlook 2013 report*, U.S. Energy Information Administration, 2013.

[2] R. Wright, C. Kravaris, "Nonlinear decoupling control in the presence of sensor and actuator deadtimes", *Chem. Eng. Sci.*, vol. 58, pp. 3243-3256, Feb. 2003.

[3] N. Jerome, W. Ray, "High-Performance Multivariable Control Startegies for Systems Having Time Delays", *AIChE J.*, vol. 32, No. 6, 1986.