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Chemical process response analysis to single and multiple input parameter deviations.

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Nowadays the chemical industry uses more complex processes. These processes produce complex products and need to decrease emissions emitting and energy consumption. These processes require more sophisticated equipment and interconnected units. Meeting these demands presents challenges in design, control, analysis, process safety, and economics. Chemical process behavior is basically nonlinear, as demonstrated during malfunctions, which lead to changes in operating parameters. Nonlinear behavior can occur in whole working range of input parameters, it can occur in specific range of parameters or under specific conditions or combination of input parameters. In some cases, nonlinear response is observed in other pieces of equipment of unit or other plant connected to plant with change in input parameters. Nonlinear behavior caused by interactions between independent parameters is hardly predictable and can be overlooked during hazard analysis, e.g. HAZOP. Response of nonlinear system can by manifested by oscillatory behavior, domino effects or high sensitivity to change in input parameters (fast change in temperature, pressure or runaway effect). Identification of nonlinear behavior to deviation of design input parameters can be done at equipment, where deviation appears but also at connected equipment and units. Including connected units to analysis has additional value in identifying domino effects or consequence effects, which can occur only on other units than the original unit of deviation. Including mathematical modeling to hazard analysis like HAZOP can increase the number of identified potentially dangerous scenarios, which are manifestations of nonlinear system behavior.

Process response to single input parameter deviations is analyzed by nonlinearity measures (NLM) (Helbig et al., 2000). NLM is suitable to analyze nonlinear response of system in chosen range of deviation values, all possible values of deviated parameter or to identify ranges, where is nonlinear behavior strongest. Morris (1991) sensitivity analysis is used to evaluate system response to multi-input parameter deviations. This method provides two information about each analyzed input. The first information is influence at system response and the second information is nonlinear effect and/or interaction with other analyzed inputs. Propylene glycol production is chosen as case study for single and multiple input parameter deviations. The chemical plant consists of a continue stirred tank reactor and two distillation columns. It was modelled with Aspen Plus Dynamics® and Matlab®. Parameters used for analysis were propylene oxide flow, water flow, cooling water temperature and cooling water flow. The analyzed process response was temperature of reactor and temperature of condenser and reboiler of both columns. The strongest nonlinearity was observed due to water flow deviation, which showed the highest NLM values. These results are compatible with Morris analysis results, which identify water flow deviations as deviations with strong nonlinear behavior and/or interactions and also they have significant influence on temperature.

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