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Abstract

Reliability and maintenance issues are part of basic process design and integration. For a given design, reliability and availability can be improved by the most appropriate preventive maintenance schedule. If the maintenance is too infrequent, then the reliability will be too low. If the maintenance is too frequent, then the maintenance reduces the system availability. Thus, the schedule for preventive maintenance for a given design must be systematically optimized.

For a new site utility systems design, reliability and availability can be improved by the appropriate choice of equipments, and their connections into the most appropriate configuration. However, maintenance cannot be neglected, as preventive maintenance can have a significant effect on the system reliability. Thus, choice of equipment, equipment configuration and preventive maintenance must all be optimized simultaneously.

Key features of the optimization problem include discrete decisions in the selection of equipment, equipment state (operation state, cold standby, hot standby, failure, and start-up), the system condition and the optimization of the maintenance schedule. It leads to a very complex system synthesis problem. Therefore, it is necessary to develop a smart modeling and design framework to overcome these difficulties.

In practice, process operation flexibility is unavoidable. The utility system should be designed with the fluctuation of process utility demands consideration, especially process steam demand variation. The operational issues of system flexibility must be integrated in the system design and optimization.

Boilers are important items in the utility system. Boilers in the system have five modes: operation state, cold standby, hot standby, failure, and start-up. The boiler system condition is the combination of different boiler state. The different system condition implies different cost.

This work has developed a methodology for a reliable boiler system design under flexible steam demands based on mathematical programming method. The effect of the system reliability analysis and uncertain steam demands on the optimization objective and constraints are analyzed in this work, and a mixed integer linear programming model (MILP) is formulated for the simultaneous optimization of operational issues of system flexibility, system reliability, and cost objectives. For the system reliability analysis, the reliability theory derived from Markov model is applied to deal with the system condition probability, which contribute to the optimization objective and constraints. The fluctuation of process steam demand is discretized to be steam demand state and its corresponding probability, and is included in the optimization objective and constraints.

The optimal design result contains the selection of boilers (number of boilers, sizes, boiler state). The scheme plan obtained from the optimization provides the operation scheme to copy with the boiler failures or steam demand variation. For example, once a boiler failure/steam demand variation is happened, measures would be taken to adjust the system condition, including boiler load sharing, boiler state switching from hot standby to operation state, etc.

The proposed methodology and computational tools comprises the development of systematic methods, guidelines and tools for the practical application of an integrated approach to energy and cost minimization in process industries, and can be utilized for the constituent process models, as well as synthesis, design and operation of centralized and distributed energy systems.

The proposed methodology will be evaluated on selected sites from industrial partners and used in the demonstration work packages.