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Uncertainty is unavoidable in chemical process design and optimization. Two-stage stochastic programming with recourse (SPR) is an important approach to the optimization under uncertainty. To solve the SPR model, this paper has analyzed the mapping relationship between the optimization constraints and the feasible region. A developed approaching feasible region algorithm (AFRA) has been preposed integrating both Benders decomposition and Monte Carlo sampling methods. The core idea of the AFRA is to keep limited constraints to the master problem to shape the augmented feasible region. The solution of this master problem is then checked by the excluded constraints to address the violated constraints. These violated constraints named critical constraints are then added to the master problem to reshape the strict feasible region. The optimal solution can be obtained without violating all the constraints by iterations. The AFRA can increase the convergence speed greatly. Two case studies are presented to validate the efficiency and convergence of the AFRA algorithm, especially for the model with large numbers of constraints.